THE UNIVERSITY OF ALBERTA

THE MIETTE FORMATION, JASPER, ALBERTA

A THESIS
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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
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by

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ABSTRACT

The Precambrian Miette Formation in the vicinity of Jasper is divisible into two members. The lower member, some 2500 feet thick, consists of a monotonous succession of interbedded and lenticular pebble conglomerates, sandstones, siltstones and argillites. The upper member, about 1600 feet in thickness, is predominantly argillaceous but contains a conglomerate with dolomite boulders up to 12 feet in diameter. Conspicuous graded bedding, together with more sporadic cross stratification, ripple marks, flute casts, scour and fill structures, occur within the formation. Convolute bedding, load casts and sandstone sills and dykes are also present. Deposition of the lower member probably occurred in a shallow-water, near-shore environment. The source, which apparently lay to the northeast, consisted largely of plutonic and metamorphic rocks. The upper member was deposited in a deeper-water environment. The rocks belonging to the Miette Formation have been deformed into a series of tight similar folds. The thickness of the incompetent argillites is considerably thicker in the axial regions of folds whereas that of the competent arenaceous strata is essentially constant. The attitude of axial-plane cleavage varies continuously from the argillaceous to the arenaceous beds. Jointing and veining are locally conspicuous. The bulk of the formation appears to be in the quartz-albite-muscovite-chlorite subfacies of the greenschist metamorphic facies. Although albite is the only feldspar in the lower member, albite and potash feldspar occur together in the upper member.

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INTRODUCTION

Rocks of Precambrian age occur in the area surrounding Jasper townsite, in the Main Ranges of the Canadian Rocky Mountains. The area under discussion is situated mainly in the Miette River valley between Old Fort Point and Geikie Station. Mapping was also carried out on Cairngorm Mountain, between Signal and Tekarra Mountains, on Whistler's Mountain and east of Angel Glacier (Fig. 1). This thesis, dealing with the Precambrian Miette Formation, incorporates the data of previous work by Charlesworth *et al.* (1960 and 1961), Remington (1960), Stauffer (1961), Griffiths (1962) and Steiner (1962).

A total of 3 months were spent in the field during the 1962 and 1963 field seasons. Emphasis was placed on the mapping of the Virl Lake and Saturday Night Lake areas (Fig. 2).

STRATIGRAPHY

Nomenclature of the Precambrian and Lower Cambrian Rocks of the Jasper Area

Strata of early Cambrian and Precambrian ages in the Jasper area have been described and named by various workers. McEvoy (1901) divided the Precambrian rocks into three unnamed units of unstated stratigraphic relationship. The first was described as fine-grained conglomerates, the second as interbedded fine-grained conglomerates and slates, and the third as argillites with calcareous sandstones. Walcott (1913, p. 340) introduced the name "Miette formation" for "massive-bedded, grey sandstones" and "grey and greenish siliceous shales" outcropping west of Jasper in the Miette River valley. Pebble conglomerates, sandstones and quartzites overlying the recessive Miette Formation were grouped into the Cavell Formation by Raymond (1930, p. 293), but the boundaries of the formation were not well defined. Allan *et al*. (1932) proposed the name "Jasper series" for a succession of buff-coloured quartzites, argillites, sedimentary breccias, slates and conglomerates. They also suggested that the Miette and Jasper units occupy a similar stratigraphic position immediately below the Cambrian Cavell Formation. The descriptions of the Cavell Formation and the Jasper "series" indicate that there may be some overlap between these units (Table I)[1].

Charlesworth *et al*. (1960 and 1961) suggested a more precise division of the Precambrian sediments. The term Jasper Formation was applied to the sandstones, pebble-conglomerates and carbonates occurring immediately below the better sorted,

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(1) Table I is based upon a lithologic correlation of mapable units in the Jasper area and gives the various names applied to these units by different workers. The change in stratigraphic position of the Precambrian-Cambrian boundary reflects the interpretation of the various workers.

Cambrian Cavell quartzites. The name Miette Formation was retained, but restricted to interbedded conglomerates, sandstones and argillites which are stratigraphically below the Jasper Formation, and which comprise the bulk of the outcrop in the Miette River valley west of Jasper. The greenish-grey argillites, siltstones, breccias and limestones underlying the Miette Formation were grouped into the Old Fort Point Formation. This formation outcrops at Old Fort Point, Muhigan Creek and Meadow Creek in the Miette River valley. At Meadow Creek an unnamed sandstone underlies the Old Fort Point Formation.

Mountjoy (1962, pp. 3-7) mapped Precambrian and Lower Cambrian strata 35 miles northwest of Jasper and proposed a two-fold division of these strata: the Gog Group, a resistant unit incorporating all Lower Cambrian and possibly older quartz sandstones, and the Miette Group, a recessive unit including all strata underlying the Gog sandstones (Table I). The Gog Group seems to be synonymous with the Cavell Formation, which in this area has priority because of first usage. The term Gog, however, has been applied to all Lower Cambrian and older sandstones in the Lake Louise-Assiniboine region (Deiss, 1940). Mountjoy using the criteria of stratigraphic position and lithology has extended the term to the Jasper-Mount Robson area, thus eliminating the poorly defined term "Cavell".

Archaeocyathus and *Olenellus* have been found in the upper part of the Gog Group north of Jasper (Mountjoy, 1962, p. 7), so Formation *A* is clearly Lower Cambrian. Since there is no visible unconformity within or beneath the Gog Group, for convenience, the Precambrian-Cambrian boundary should be drawn arbitrarily at the base of the oldest formation containing Lower Cambrian fossils. This would place the boundary within the Gog Group, between two formations of similar nature and unknown areal extent. Following Okulitch (1956, pp. 728-730), it is recommended that the boundary be placed between the Miette and Gog Groups.

<table>
<tr><th>WALCOTT 1913</th><th>RAYMOND 1930</th><th colspan="2">ALLAN et. al. 1932</th><th>CHARLESWORTH et. al. 1960 & 61</th><th>MOUNTJOY 1962</th><th>THIS THESIS</th><th></th></tr>
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TABLE I

STRATIGRAPHIC NOMENCLATURE OF THE PRECAMBRIAN AND BASAL CAMBRIAN ROCKS JASPER, ALBERTA

In this thesis the name Miette Formation is used as defined by Charlesworth et al. (1960 and 1961) in order to maintain continuity with previous theses by Remington, Stauffer, Griffiths and Steiner. This formation is the uppermost of three formations to which the term Miette Group has been applied. The writer is aware of the necessity of renaming the "Miette Formation", but this is not within the scope of the thesis.

The Miette Formation

The Miette Formation lends itself to a natural two-fold division: a lower, well exposed, predominantly arenaceous member; and an upper, poorly exposed, argillaceous member. The lower member underlies a large area in the vicinity of Jasper, with the best outcrops in the Miette River valley to the west (Fig. 2). An almost complete section (2,200 feet) was measured along the Canadian National Railway grade, on the southwest limb of the Muhigan Creek anticline (Fig. 2). This is the type section (Appendix). The basal 150 feet are not exposed. Another 700-foot section was measured from the top of the Old Fort Point Formation on the northeast limb of the Muhigan Creek anticline, east of the mouth of Muhigan Creek (Appendix). Correlation between the two sections was not possible.

The contact between the upper and lower members is drawn at the top of the highest sandstone bed underlying bluish-grey argillites (Pettijohn, 1957, p. 342) of the upper member. The contact is not restricted to one stratigraphic horizon since argillites of the upper member interfinger with sandstones of the lower member in the type section (Fig. 3).

The upper member outcrops on Cairngorm Mountain, Whistler's Mountain, east of Angel Glacier, at Saturday Night Lake, on Tekarra Mountain, along Minaga Creek and at Pyramid Lake. The member consists, predominantly, of argillite, having

very poor outcrops. A structural interpretation, for this reason, was impossible at almost all localities and a reliable thickness (1600 feet) was obtained only at Tekarra Mountain. This is the type section (Appendix).

The section at Cairngorm Mountain is included in the appendix, not because it is a particularly good section but rather because of its inaccessibility. Since the structure at Cairngorm Mountain was not fully determined, it is quite possible that some repetition of beds by faulting may exist. At Whistler's Mountain 1 1/2 miles of alpine meadow cover the upper member, below Indian Ridge. Outcrops are confined to the cirque on the north slope of Whistler's Mountain. The Jasper Formation is not exposed at Mount Edith Cavell and isolated outcrops in the creek valleys east of Angel Glacier could not be assimilated into a section of the upper member.

Correlation within the upper member is, at this time, impossible. Black limestone and dolomite boulder conglomerates have been found only within the upper member. For this reason, a part of the Saturday Night Lake map-area (Fig. 4) has been assigned to the upper member.

The Miette Formation overlies, apparently conformably, the Old Fort Point Formation. Where the contact is gradational, it is placed at the base of the lowest pebble conglomerate overlying the silty to sandy, greenish and bluish-grey argillites of the Old Fort Point Formation (Evans, 1961, p. 19). This type of contact is well exposed east of Old Fort Point. At Geikie Station, however, the contact is sharp. An abrupt change in lithology from argillite of the Old Fort Point Formation to pebbly sandstone of the Miette Formation can be observed.

In the vicinity of Jasper, the upper contact of the Miette Formation, visible at Tekarra Mountain, Pyramid Lake and Cairngorm Mountain, is conformable and shows some gradation. Northeast of Jasper in a railway cut, this same contact is very sharp but faulted (Charlesworth, personal communication, 1963). Walcott (1928) reported

the Cambrian-Precambrian contact as an erosional unconformity in the Mount Robson area to the west.

Correlation

Reesor (1957, p. 160) correlated the Horsethief Creek "series" (Windermere area) with the Hector and Corral Creek Formations (Lake Louise area) and the "Miette formation" (as described by Walcott, 1913). This correlation was based on the stratigraphic position and occurrence of quartz-pebble conglomerate in these formations. Mountjoy (1962, p. 5) preferred to correlate the "Miette Group" with the Hector and Corral Creek Formations, only, on the basis of stratigraphic position below the "Gog Group". Comparing only the lithologies, Evans (1961, p. 25) correlated the Old Fort Point Formation with the type section of the Hector Formation.

The "Miette Group", as Mountjoy suggested, can be correlated by stratigraphic position between Jasper and Lake Louise. It is doubtful whether the Miette Formation can be traced that far.

LITHOLOGY

Lower Member

General. A monotonous succession of alternating arenaceous and argillaceous beds makes up the lower member. The proportion of arenaceous to argillaceous beds in the type section is two to one.

Individual arenaceous beds are not traceable for more than 150 feet along strike; even strata(Howell et al., 1960, p. 281) up to 200 feet change in thickness and composition laterally and are not recognizable over a distance greater than three miles. Argillaceous strata seem to be more continuous.

Marker horizons are absent. The only criterion of approximate stratigraphic position is the color of the arenaceous beds: the lower three quarters are greenish-grey, whereas the upper quarter is light brownish-grey.

It is impossible to disintegrate the well-consolidated arenaceous rocks without crushing the grains. Mechanical analyses, therefore, are of no use in determining grain size and were not attempted. Grain-size sorting is generally poor. Stauffer (1961, p. 13) suggested that there is an increase in sorting with decreasing grain size. The majority of grains in all size ranges are angular to subrounded.

Conglomerate[(2)]. Conglomerates form the basal part of graded beds in most instances; some, however, are present as isolated beds. Bedding thickness ranges from a few inches to 10 feet, but is most commonly about 1 foot. The color, on a fresh surface, is usually greenish grey tending to light brownish grey in the upper part of the member.

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(2) The following lithologic descriptions incorporate data by Remington (1960), Stauffer (1961), Griffiths (1962), Steiner (1962) and the writer.

Weathered surfaces are usually light grey, commonly spotted with rusty stains. The grain size averages 10 millimeters, with a range from 2 to 40 millimeters. This range is for detrital quartz, feldspar and rock fragments, but does not include argillite fragments and dolomite pebbles. Argillite fragments are usually very angular and slabby, lying in the plane of bedding. Some fragments of exceptional length (80 centimeters) were noted, but the average length is about 10 centimeters. The matrix of the conglomerates is a mixture of sand, silt and clay; sand being the dominant constituent.

TABLE II

CONGLOMERATE COMPOSITION
Lower Member

Constituent	Range %	Average %
PHENOCLASTS	25 - 70	65
Quartz	65 - 95	90
Feldspar	5 - 20	10
Chlorite and mica	0 - 25	Trace
Argillite fragments	0 - 40	Trace
MATRIX	30 - 75	35
Quartz	50 - 65	60
Feldspar	5 - 25	10
Chlorite and mica	15 - 30	20
Carbonate	5 - 25	10
Accessory minerals		Trace

The composition of the conglomerates is given in Table II. Quartz phenoclasts of the vein type (Folk, 1961, pp. 66-77) are predominant, although recrystallized and strained metamorphic quartz was also identified. Plagioclase was the only feldspar

found. Small feldspar pebbles studied by Remington, Stauffer and Griffiths show chessboard twinning (for a detailed discussion see Griffiths, 1962, pp. 19-21). Chlorite pebbles are relatively scarce in the lower part of the member but become more common in the upper 500 feet. Muscovite flakes up to 7 millimeters in diameter, are found throughout the member. Argillite fragments are concentrated in conglomeratic beds overlying argillite. Locally, dolomite pebbles are common; the pebbles contain abundant rounded structures, possibly of algal origin (Griffiths, 1962, p. 12).

The low phenoclast percentage in Table II is found in paraconglomerates (Pettijohn, 1957, p. 261). Three outcrops of this rock type are known in the Jasper area:

1. Tekarra Creek map-area (Steiner, 1962, p. 12). Paraconglomerate is present as a 6-inch bed, 800 feet above the base of the Miette Formation.

2. East of Old Fort Point, near the Jasper Park Lodge reservoir, a 3-foot bed of paraconglomerate outcrops. Charlesworth (personal communication, 1963) stated that this outcrop is close to the base of the Miette Formation.

3. Virl Lake map-area (Fig. 2). In the type section an 8-foot bed of paraconglomerate outcrops 750 feet east of the Canadian National Railway tunnel. The bed lies 475 feet above the base of the Miette Formation (Fig. 7).

The lithology at these localities is similar, ranging from a lithic paraconglomerate to a conglomeratic argillite (Plate I). Pebbles range in abundance from 20 to 30 per cent and are predominantly plutonic quartz and argillite. Steiner (1962, p. 12) also reported granite granules and quartzite pebbles. All pebbles, regardless of lithology, are subrounded. The sand-size fraction is absent except for a few grains in the very-coarse-sand range. The matrix consists of unlaminated, silty argillite.

Sandstone. This is the dominant rock type in the lower member. Beds range in thickness from a few inches to 15 feet, but are most commonly 2 1/2 feet. The color on a fresh surface varies from greenish grey to brownish grey; weathered surfaces are usually lighter in color. Coarse sand is the prevalent grain size. Generally, a matrix of silt and argillite makes up 15 to 25 per cent of the rock; carbonate cement is present locally.

TABLE III

SANDSTONE COMPOSITION
Lower Member

Constituent	Range %	Average %
Quartz	50 - 75	65
Feldspar	5 - 25	10
Chlorite and mica	15 - 25	20
Carbonate	0 - 25	5
Accessory minerals		Trace
15% rock fragments are included in the tabulation above		

The composition of the sandstones is given in Table III. The average lithology should be described as a lithic sandstone, although some beds are arkosic sandstones (Pettijohn, 1957, p. 291). Quartz is present in four types: plutonic, vein, recrystallized metamorphic and stretched metamorphic (Folk, 1961, pp. 66-77). Single and composite grains of vein quartz are most abundant. Albite is the only feldspar present. Some albite grains show alteration to chlorite and sericite and replacement by carbonate, whereas other grains have a fresh appearance. Siderite and calcite are present, commonly in the matrix as isolated crystals; in the few instances where carbonate forms the cement, cavernous weathering of the sandstone

has taken place. Chlorite is restricted to the matrix and is responsible for the characteristic green color of the rock. In the upper part of the member the color of iron oxide overshadows the chlorite. Mica is present as detrital muscovite, metamorphic sericite in the matrix and scattered detrital biotite flakes. The non-opaque, heavy minerals are zircon, tourmaline, rutile and apatite. Their stratigraphic distribution was tabulated by Griffiths (1962, Fig. 3). The opaque minerals are ilmenite, magnetite and pyrite. Cavities left by weathered-out pyrite cubes are up to 1 1/2 inches in diameter (Plate 1). The rusty stains on weathered surfaces are due to the weathering of pyrite.

Siltstone and argillite. These two lithologies are intimately related, forming a continuous sequence from siltstone through argillaceous siltstone and silty argillite to argillite. The uppermost part of a graded bed is commonly siltstone or argillite. These lithologies, however, also make up strata up to 300 feet thick.

Bedding thickness varies from a few millimeters in argillite to 2 centimeters in siltstone. Color lamination is common, particularly in argillite. The color on a fresh surface varies from greenish grey to grey, with dark grey laminations in argillite. Siltstones are frequently stained by limonite giving a light brown coloration. Weathered surfaces of siltstone are light brown; of argillite dark rusty brown.

The composition is extremely variable. The major components are quartz, some feldspar, muscovite, chlorite, heavy minerals and, locally, carbonate cement. Quartz is most abundant in the silt-size fraction, as are the heavy minerals. Muscovite is present as detrital flakes; sericite is abundant. Pyrite is common in small quantities throughout the section.

Upper Member

A composite section of the upper member has been divided into 8 units. The units are described separately from the base upwards. Most descriptions are from the type section at Tekarra Mountain.

Unit 1. (Thickness 1175 ± 25 feet at Tekarra Mountain)

The unit consists of bluish-grey argillite with infrequent dark grey laminations. Since siltstone beds are absent and the silt content is very low, this unit has a homogeneous texture. Color and texture distinguish this unit from argillite in the lower member.

The basal part of the unit outcrops along Minaga Creek, where it interfingers with sandstones belonging to the lower member. Further outcrops are found at Cairngorm Mountain, along the road-cut on the east shore of Pyramid Lake, on Whistler's Mountain and in the creek valleys east of Angel Glacier.

Unit 2. (Thickness 20 feet at Tekarra Mountain)

Arkosic sandstone and conglomerate with thin interbedded argillite make up this unit. Graded bedding was not recognized. The arenaceous beds, light brown in color, are composed of 50 per cent quartz[(3)], 10 per cent altered plagioclase, 10 per cent potash feldspar[(4)] relatively fresh, 15 per cent rock fragments and 15 per cent argillaceous matrix. Argillite beds comprising less than a third of the unit are generally less than 2 feet thick and contain up to 15 per cent biotite. The only detrital mica in the arenaceous beds is a trace of muscovite.

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(3) Percentage composition was determined from thin-sections of representative hand specimen.

(4) Potash feldspar was stained with sodium cobaltinitrate (Hays and Klugman, 1959).

A 50-foot sandstone unit underlying unit 4 at Cairngorm Mountain could possibly be correlated with this unit. Along the south shore of Saturday Night Lake a similar unit of sandstone and conglomerate underlies unit 4. This arenaceous unit is approximately 100 feet thick, but closely resembles unit 2 at Tekarra Mountain.

Unit 3[(5)]. (Thickness 6 feet at Saturday Night Lake)

This unit, at Saturday Night Lake, consists of black, argillaceous limestone with thin, sometimes lenticular, interbeds of calcareous siltstone (Plate VII). Some silt lenses contain fragments of limestone which appear to be intraformational breccia. Ovoid particles up to 1 millimeter in length were observed in thin-section but due to the recrystallized nature of the limestone no internal structure was found (Plate VII).

Near the peak of Whistler's Mountain a 5-foot limestone unit outcrops in the cirque. The limestone is thin bedded (1 to 2 centimeters), argillaceous, and black in color. Oval depressions (maximum size 5 by 3 centimeters) up to 2 millimeters deep are common on some bedding planes. The interior lining of the depressions is light grey in contrast to the black limestone. Dr C.R. Stelck (personal communication, 1963) was of the opinion that the depressions are non-organic in origin. Recrystallization of the limestone has occurred, particularly, along the bedding planes where calcite crystals up to 2 millimeters in diameter are common. Thin beds of black, argillaceous limestone in argillite were found in a stratigraphic interval of 10 feet, along the road-cut east of Pyramid Lake. East of Angel Glacier two outcrops of massively bedded, black, argillaceous limestone suggest a minimum thickness of 15 feet. Whether the various limestone units can be correlated is not known, since the stratigraphic position is only certain at Saturday Night Lake.

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(5) Since units 2 and 3 have not been found together at any one locality, it is impossible to determine which is the younger. Both, nevertheless, underlie unit 4--unit 2 at Tekarra Mountain and along the south shore of Saturday Night Lake, and unit 3 west of Saturday Night Lake.

Unit 4. (Thickness 90 feet at Tekarra Mountain, 50 feet at Cairngorm Mountain and 70 feet at Saturday Night Lake)

The unit is made up of dolomite-boulder conglomerate with thin interbeds of quartz-pebble conglomerate and argillite. The dolomite blocks are grey in color, weathering tan and vary in size from cobbles to boulders 12 feet in diameter. The largest boulders were found at Saturday Night Lake; the maximum size at Tekarra Mountain is 5 feet in diameter, averaging 2 1/2 feet. The boulders are subrounded and do not show any preferred orientation even if they are elongated in one dimension. The boulder conglomerate beds vary from 10 to 20 feet in thickness, boulders making up about 65 per cent of each bed. The dolomite is silty, containing about 10 per cent quartz; ovoid particles (Plate VIII) make up 65 per cent of the rock. The boulders are cut by calcite veinlets. The matrix of the boulder conglomerate is quartz pebble conglomerate having, itself, a matrix of calcareous, arkosic sandstone. The maximum size of the quartz pebbles is 1 centimeter; the pebbles are sub angular to subrounded. The sand fraction contains 20 per cent potash feldspar and 5 per cent plagioclase. At Saturday Night Lake no potash feldspar was found. The lower part of the unit contains numerous argillite shards. The unit is absent at Pyramid Lake and, if present, covered at Whistler's Mountain and Angel Glacier.

Unit 5. (Thickness 35 feet at Tekarra Mountain)

The unit consists of quartz-pebble conglomerate with a grey to light grey matrix of arkosic sandstone which weathers dark brown. The conglomerate contains 20 per cent potash feldspar as pebbles and sand-size grains. Argillite fragments were found throughout the unit. Carbonate cement is present in patches.

Unit 6. (Thickness 155 feet at Tekarra Mountain)

Medium-grey, silty argillite makes up this unit. Repeated graded bedding, from silty argillite to argillite, takes place over an interval of 1/4 to 1/2 inch. Near

the top of the unit medium-grained sand was found at the base of the graded beds.

Unit 7. (Thickness 17 feet at Tekarra Mountain)

The unit consists of thick-bedded, light brown, arkosic sandstone. Potash feldspar is rare. The composition is 60 per cent quartz, 15 per cent plagioclase, 10 per cent rock fragments, 15 per cent matrix and some carbonate cement.

Unit 8. (Thickness 105 feet at Tekarra Mountain)

Argillite, with silt and some sand, forms graded beds up to 4 inches thick. Potash feldspar is abundant in the sand size fraction. Detrital biotite and muscovite were found. The color is medium grey on a fresh surface, weathering dark rusty brown.

Stretched metamorphic quartz in composite grains is nearly as abundant as plutonic quartz in the upper member. The grains are generally subangular to subrounded. Quartz overgrowths on detrital grains were not observed.

Potash feldspar (microcline) seems to be confined to some beds in units 2 and 4-8; 60 per cent of these beds contain potash feldspar. Both plagioclase (An 5-15) and potash feldspar show corrosion by carbonate where this is present as cement. Although, the potash feldspar is quite fresh, some grains show alteration to sericite and chlorite. Biotite is always partially altered to chlorite. Argillite forms the matrix in all arenaceous beds, accompanied by varying amounts of carbonate cement.

Heavy minerals were separated from 5 samples. A persistent coating could not be removed from the grains by repeated washing with warm, dilute hydrochloric acid. Finally the separates were boiled in the acid. Although this treatment cleaned the grains, the writer is aware that any apatite that may have been present was also dissolved. The non-opaque, heavy minerals observed were tourmaline, zircon and rutile. The opaque minerals were not counted, but ilmenite, magnetite and pyrite

were present in all samples. Tourmaline is most abundant in all shades of brown and green, but some grey and blue grains were also found. Zircon grains are either clear or some shade of violet ranging from very light to almost opaque; the ratio of clear to violet grains increases stratigraphically upwards. Globular inclusions are very common in zircon, whereas acicular inclusions, which always parallel the crystallographic c-axis, are quite rare. The stratigraphic distribution of the heavy minerals is set out in Table IV.

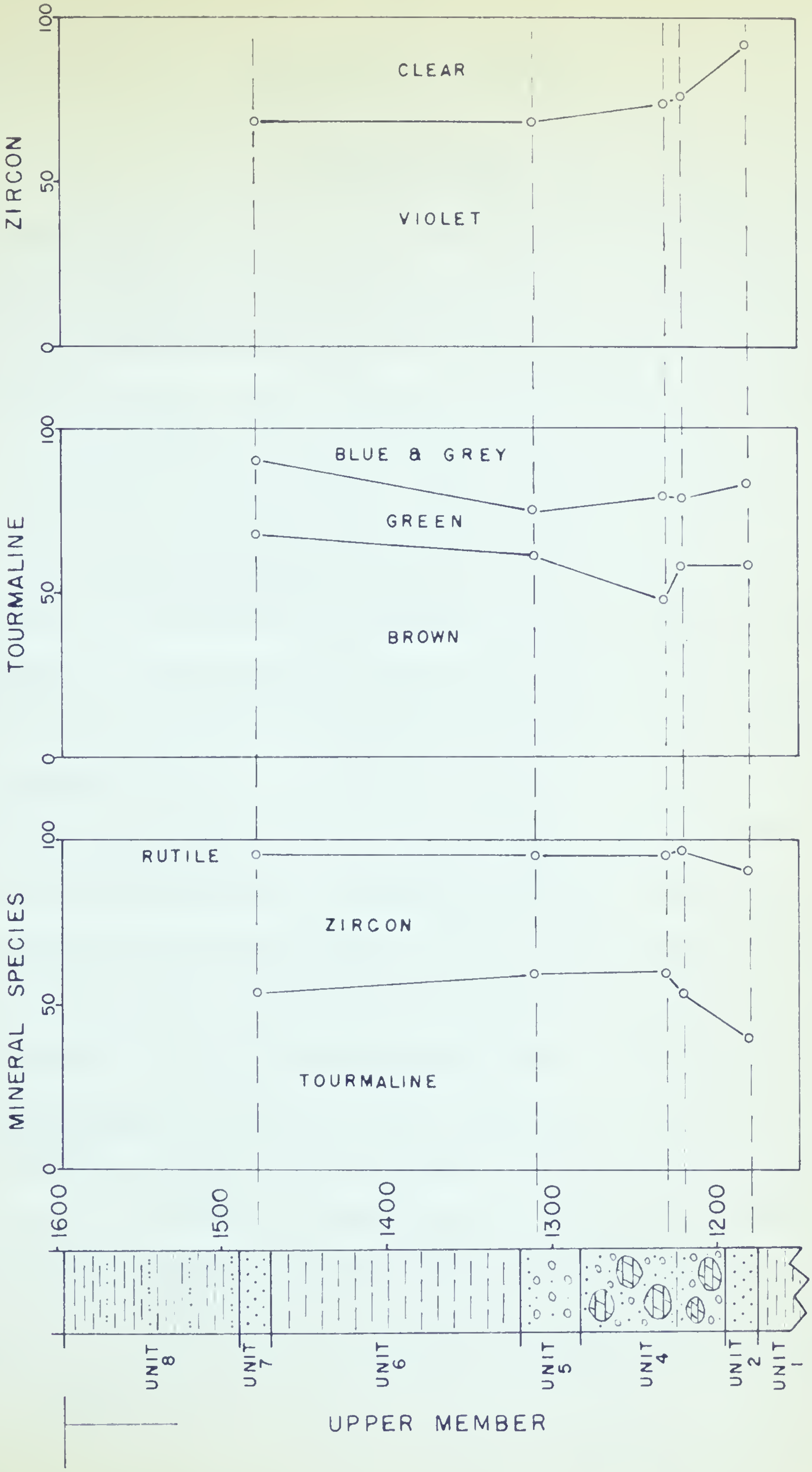

TABLE IV

DISTRIBUTION OF HEAVY MINERALS

AT

TEKARRA MOUNTAIN

SEDIMENTARY STRUCTURES

Primary Structures

Graded bedding. The most conspicuous structure in the lower member is graded bedding, with gradation from conglomerate or sand, in the lower part of a bed, to fine sand, silt or argillite at the top. A decrease in the maximum grain size upwards is accompanied by an even distribution of the finest fraction in the bed.

Graded beds vary in thickness from 1 foot to 6 feet, but are most commonly 2 1/2 feet thick. Lateral variation in the graded beds is so rapid that a bed 4 feet thick may grade from conglomerate to sand at one locality; within tens of feet, the same bed may consist only of conglomerate or grade to argillite, without changing thickness. Graded bedding is also found in thick argillaceous strata. Gradation from siltstone to argillite takes place over a distance of a few millimeters to 5 centimeters.

Stauffer (1961, pp. 6 and 10) described two types of graded bedding: continuous and discontinuous. With respect to the latter, Stauffer stated, "... discontinuous type of graded bedding involves a number of sudden reductions in grain size from bottom to top such that the graded sequence consists of up to four beds, each with its own fairly constant grain-size range". The connotation of the term graded bedding is a continuous change in grain size. One of the criteria in differentiating beds is an abrupt change in grain size. "Discontinuous graded bedding" can, therefore, be found in any bedded stratum(6) by picking the coarsest bed as the base. "Discontinuous graded bedding", for this reason, is not a useful term.

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(6) The term stratum is used as defined by J.D. Dana in 1895 (Howell et al., 1960, p. 281).

Graded bedding in the upper member is confined to units 6 and 8. A few millimeters of sand form the basal part of argillite beds averaging 2 centimeters in thickness. Gradation from sand to argillite is confined to the lower half of each bed.

Cross-stratification. Although reported as common in the lower member, by previous workers, cross-stratification in the Virl Lake and Saturday Nigh Lake map-areas was confined to argillaceous siltstones, where attitudes were impossible to measure. The following description, therefore, is based principally on the work of Remington (1960), Stauffer (1961), Griffiths (1962) and Steiner (1962).

All types of cross-stratification described by McKee and Weir (1953) have been reported. The cross-strata are thinly bedded in coarse-grained or pebbly sandstone. Less matrix in cross-stratified, arenaceous beds gives them a lighter color, which is quite conspicuous in the field. The dip directions of cross-strata measured by previous workers were combined into one rose diagram (Fig. 6). The average current direction is S 60° W.

Cross-stratification was not observed in the upper member, but Mountjoy and Aitken (1963, p. 166) report 11 readings from the Snake Indian River, 35 miles northwest of Jasper. The readings were taken on strata within the uppermost 500 feet of the "Miette Group" which is equivalent to the top of the upper member of the Miette Formation. The average current direction, indicated by these readings, is S 45° W (fig. 6).

Ripple marks and flute casts. Surface markings on bedding planes are frequently suggestive of ripple marks and, at times, flute casts. Good examples of both are rare. Stauffer (1961, p. 13) reported two positive identifications of ripple marks of the interference type. Griffiths (1962, p. 5) identified two small flute casts.

Scour-and-fill structures. Scour-and-fill structures are common where argillite beds are overlain by coarse sandstone or conglomerate. Shallow channels (2-5 centimeters deep, 10-50 centimeters wide) were eroded and filled with coarse sediment. Argillite fragments are frequently found in the channels, but are not confined to them. Between Dorothy Lake and Virl Lake, a deep, multiple scour channel shows erosion of 13 feet of argillite and siltstone. Four successive banks on the north side of the channel are visible (Fig. 8 and Plate II) over a horizontal distance of 22 feet. Massive, pebbly sandstone fills the channel, lying adjacent to undisturbed, laminated argillite in the bank of the channel. The southern limit, and thus the width of the channel, could not be established.

Lenticularity of beds. The Virl Lake area was chosen as a map-area, because of the relatively good outcrop compared to areas mapped by previous workers. It was attempted to ascertain the continuity of the arenaceous strata by "walking out" the beds and by measuring numerous sections.

Steiner (1962, p. 18) explained the use of maximum grain size in local correlation of arenaceous beds. This method has been found by the writer to be inapplicable, since the lateral change in grain size is too irregular. Individual beds either grade into argillite or lens out between other arenaceous beds; they cannot be traced for more than 150 feet along strike. Strata up to 200 feet thick change markedly in thickness and cannot be recognized over a distance greater than three miles along strike. The arenaceous strata, therefore, are considered as lenticular bodies of variable dimensions.

Penecontemporaneous Structures

Convolute bedding. Stauffer (1961, p. 13) described the only known example of convolute bedding in the lower member. This slump structure is in a fine-grained sandstone bed about 10 inches thick. The "fold" is recumbent to the southwest, indicating an original slope of the depositional surface to the southwest.

Load casts. The lower surfaces of arenaceous beds are frequently marked by load casts where the underlying material is argillite or siltstone. Casts up to 4 feet across have been observed, although the average width is 1 1/2 feet. The relief of the load casts varies from a few inches to 1 foot. Individual casts are difficult to recognize where, as is commonly the case, bedding is undulatory. Stauffer (1961, p. 13) observed ruptured load casts that had formed two peaks. He also described distorted "flow casts" which indicate an inclination of the depositional surface to the southwest.

Sandstone sills and dykes. Sandstone sills and dykes were observed in an outcrop between Dorothy and Virl Lakes (Fig. 3) which is 50 feet north of the axis of the Iris Lake anticline. This locality is easily accessible from the Dorothy Lake trail.

The upper 13 feet of a 60-foot stratum of laminated argillite and siltstone terminate against a sand-filled scour channel (Fig. 8). Four distinct banks (A, B, C and D; Fig. 8) of the channel are visible (Plate II). Where a bank and the bottom of the channel intersect, sandstone protrudes into the argillite. At "A" (Fig. 8) a sandstone wedge extends 22 feet into the argillite; at "B" the sandstone protrudes 12 feet. The two oldest argillite banks overhang the channel, so that it is difficult to determine the extent of protrusion at "C" and "D" (Fig. 8). In both cases it is less than one foot.

The lower and upper surfaces of the sandstone wedges are discordant with bedding in the argillite (Fig. 8). This indicates that the sandstone was not deposited

in situ, but that it intruded the argillite. The lower two sandstone wedges, which tend to parallel bedding, are called sills.

The sills are not continuous throughout their length in outcrop but are interrupted by narrow zones of laminated argillite (points 8, 9 and 11; Fig. 8 and Plate IV). It appears probable that continuity in each sill exists in the third dimension. Small-scale sills (less than 1 foot long and 1 inch thick) are present in the argillite near the scour channel between sills A and B (Plate III).

Small dykes originating from the sills intrude the argillite. The most northerly dyke is broken and off-set parallel to bedding (point 10, Fig. 8 and Plate IV). The stratigraphically higher part has moved towards the axis of the anticline. Two smaller dykes are associated with thinning in sill B and pinching in sill A (Plate IV). An arcuate sandstone mass joins sill B to the scour channel (Plate III).

There are no internal structures in the sills or dykes--mesoscopic or microscopic (Turner and Weiss, 1963, p. 15)--which are composed of lithic sandstone. Up to 15 per cent quartz pebbles are present in the adjacent channel sandstone; however, only a few pebbles were noted in sills A and B near their junction with the channel.

There are two periods during which the sandstone dykes and sills may have formed: First, before consolidation of the sediments; secondly, at the time the rocks were folded, presumably during the Laramide orogeny. Evidence for the latter is found in the attitude of the dykes. All dykes tend to be parallel, but an accurate measurement of the attitude was possible only on the largest dyke, which parallels the cleavage in the argillite (dyke N 73° W/vertical, cleavage N 70° W/88° N). The dyke, however, is disrupted, indicating that intrusion had occurred before bedding plane slip, in the process of folding, took place.

With respect to the pre-consolidation theory of formation, the argillite was partially consolidated at the time the scour channel was eroded and filled with pebbly sand saturated with water. Sedimentation continued with the deposition of alternating strata of argillaceous material and sand. In order to effect intrusion, a pressure gradient must be set up between the body to be intruded and the intruding material. Pettijohn (1957, p. 192) suggested that intrusion can take place under hydrostatic pressure. This does not seem feasible in this instance, since to maintain hydrostatic pressure the permeability in sand and especially in the argillaceous strata must be such that equilibrium of fluid pressure can be maintained. Levorsen (1954, p. 396) listed four stages for the removal of water from sediments: 1) mechanical rearrangement, 2) dewatering, 3) mechanical deformation and 4) recrystallization. The last three stages could be considered as nearly irreversible processes, which would disrupt the equilibrium of hydrostatic pressure. "The return to a state of equilibrium may be a long slow process where the opposing forces are nearly equal and the isolated reservoir" (in this case the channel) "may have excess pressure over a long period of time" (*ibid.*, pp. 397).

The excess fluid pressure in the scour channel would have very little effect on any flat surface such as a bedding plane; however, the banks would be subject to the attack of differential pressure, especially at the intersections between the bank and the bottom of any one of the multiple channels. At these points the sills intruded the argillite. Further complications exist at the origin of sill B.

Initial intrusion may have been triggered by a local disturbance. Although this is not a prerequisite for the sand intrusion, it would explain the existence of planes of weakness along which the dykes were intruded. Deformation during the Laramide orogeny could have rotated the dykes into the plane of cleavage, as the two oldest banks of the channel were moved into an overhanging position.

Similar conditions necessary for sand intrusion must have existed in numerous parts of the lower member, but other such structures have not been recognized.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

Lower Member

Provenance. An uplift in the source area at the close of Old Fort Point time is marked by the appearance of coarse detrital material in the lower member. Acid-plutonic rocks probably dominated in the source terrain, as indicated by the abundance of plutonic quartz and feldspar. Large fragments of these minerals suggest the presence of pegmatites, and minor amounts of stretched quartz point towards the presence of metamorphic rocks. The heavy mineral suite (tourmaline, zircon, apatite and rutile) is of little aid in discriminating among the various source rocks, as it contains only ultrastable minerals. Stauffer (1961, p. 30) suggested that intrastratal solution rather than attrition is responsible for the absence of less stable minerals. Selective solution after deposition is probable, since feldspar and angular fragments of tourmaline and apatite have been found in the sediments. The only detritus of sedimentary origin are cobbles and pebbles of silty dolomite, which occurs locally.

Age determinations on detrital mineral grains have been carried out by previous workers. Stauffer (see Steiner, 1962, p. 50) worked on detrital zircons and obtained an age of 1331 ± 190 million years[7]. Steiner (1962, p. 57) worked on detrital muscovite and obtained a maximum age by K/A dating of 1776 ± 90 million years. The problem in dating detrital muscovite is the inevitable updating during later metamorphism (Evans et al., 1964, p. 36). The median diameter of detrital flakes used by Steiner in obtaining his maximum age was −0.75 phi; smaller grains gave younger ages in all cases. Steiner's dating of muscovite may indicate that the source terrain lay within the Churchill Province of the Canadian Shield.

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(7) Age determination by the U.S. Geological Survey, Geochemistry and Petrology Branch using the lead-alpha method.

The dip-direction of cross-stratification (Fig. 6) indicates that drainage from the source area was in a southwesterly direction. Convolute bedding and flow casts show an inclination of the depositional surface in the same direction. Transportation appears to have been rapid as conglomerates are abundant. The angularity of the pebbles and sand grains suggests that the source was relatively close to the site of deposition.

Depositional environment. The conditions under which the lower member was deposited can be inferred from some of the primary structures, although only the general features can be ascertained. Pettijohn (1957, pp. 170-171) distinguished two distinct types of graded bedding: one with decreasing grain size upwards, where the finest fraction is confined to the top of the bed; the other with decreasing of the coarse grade upwards, where the finest fraction is distributed throughout the bed. The two types are real, and a descriptive name for each could be used, but Pettijohn (*ibid.*) classified the types as to mode of formation. He referred to graded bedding with decreasing grain size upwards as grading produced by a waning current, and graded bedding with decreasing of the coarse grade upwards as grading produced by differential settling from turbidity flow. Previous workers have described the graded bedding of the lower member as being of the "waning current type, described by Pettijohn (*ibid.*)". The writer does not agree with this terminology, since each graded bed in the lower member has an argillaceous matrix. The grading was probably caused by rapid dumping of the sediment out of the transporting current, which *sensu lato* could be considered as turbidity flow. The poor sorting also indicates rapid accumulation without reworking of the sediments.

The restricted lenticular nature of the individual beds show that the sandstone and conglomerate were indeed channel deposits. Steiner (1962, pp. 15-41) in his

discussion on paleogeography concluded that a number of "mappable shoestring sands" could be delineated. A deltaic environment was postulated by Remington (1960, p. 22) and Stauffer (1961, p. 32). Steiner (1962, pp. 32-38) carried this idea further, and described two distinct deltaic phases: constructional and destructional.

> "The constructional phase consists of the classical top-set, fore-set, and bottom-set beds. The linear shoestring sands in the top-set beds represent distributory channels. A destructional phase of delta building is characteristic of large marine deltas, it immediately follows the constructional phase and may begin even before construction is entirely completed. The destructional phase is a period of compaction and modification of rapidly extending front lines. In the destructional phase winnowing of fine sediment and concentration of coarse material into thin veneers, linear beach ridges and linear barrier islands takes place."
> (ibid., p. 33)

The writer's study of the Virl Lake area showed no indication of "mappable shoestring sands". Winnowing of the sandstones has been observed in cross-stratified beds only. A number of weak points in Steiner's presentation are

1. Steiner used only seven detailed sections as control points for a palinspastic reconstruction of an area of 20 square miles.

2. The data differentiating between constructional and destructional deltaic phases came, almost exclusively from the Tekarra Creek map-area and was extrapolated for 8 miles to Geikie Station.

3. "Shoestring sand G" was the only stratum correlated by maximum grain size; the other seven "shoestring sands" were correlated by stratigraphic position.

4. The same maximum grain size measurements were used to establish the channel trend of "shoestring sand G". However, there are not enough control points to permit interpretation of a meaningful trend (ibid., Fig. 8).

5. A few discrepancies can be found between Steiner's maximum grain size logs (ibid., Fig. 4) and the isopach map of "shoestring sand G" (ibid., Fig. 7). The

thicknesses picked on the logs differ from those given on the isopach map by 14 and 16 feet, respectively, for the Miette Avenue and Whistler-Mountain-Trail control points. The Ski-Lodge-Road control point is omitted on the isopach map, and a thickness of 27 1/2 feet at its locality is inferred. However, a thickness of 55 feet is picked on the maximum grain size log.

The writer is of the opinion that Steiner had insufficient data to conclude linearity and mappability of the arenaceous strata in the Jasper area.

A detailed picture of the depositional environment cannot be substantiated, since diagnostic features are lacking. However, a number of points can be established. Deposition probably took place in a near-shore environment. This may have been shallow water or sub-aerial. The latter is suggested by the multiple scour channel which must have been incised into partially consolidated argillite. The arenaceous strata represent distributory-channel deposits; the argillaceous strata were deposited on mud flats or interdistributory bays. Individual graded beds may have been annual deposits. Argillite fragments suggest intraformational erosion. This does not imply that winnowing occurred during this process of erosion and redeposition. Paraconglomerate beds may indicate that the beds were disrupted by subaqueous mudstreams (Pettijohn, 1957, p. 266). Rapid accumulation of the arenaceous sediment was probably the rule, interspaced with relatively longer periods of quiescence during which argillaceous material was deposited. The whole area was subsiding and was able to receive a large volume of sediments without any large scale reworking of the individual deposits.

Upper Member

Deposition of the upper member began in a deep water environment, although the lowest argillites interfinger with arenites of the lower member. The uniform texture of unit 1 and the absence of arenaceous beds in this unit indicate that deposition took

place in a deep-water environment.

The source of most of the arenaceous beds was probably very similar to the one described for the lower member. Metamorphic quartz is more abundant; the non-opaque heavy mineral suite is very similar. These minerals indicate that the source terrain consisted of metamorphic, plutonic and some pegmatitic rocks.

Two constituents of the detritus are different in the upper member: potash feldspar and a concentration of dolomite boulders in some beds. Pebble-sized, potash feldspar may have been derived from pegmatites, whereas the smaller grains could be from schists, gneisses, granites, etc. The presence of dolomite boulders show that sedimentary rocks were being eroded during the deposition of the upper member. Both dolomite boulders and quartz pebbles are subangular to subrounded. It is doubtful whether carbonate and quartz having such vastly different size and resistance to abrasion were transported the same distance. The source terrain contributing plutonic and metamorphic detritus was not the source of the carbonate boulders. Either, the source was a partially consolidated sedimentary sequence containing carbonate beds, or the detritus of two distinct sources was mixed during deposition.

1. Submarine slumping may have disrupted bedded carbonates, and deposited the blocks in a deeper-water environment. Bedded carbonates in the upper member have been reported by Mountjoy (1962, p. 5) from the Snake Indian River, 35 miles northwest of Jasper. These beds, or their equivalents, may have been the source of the boulders. The apparent local occurrence of unit 4 and the varying stratigraphic positions favour this mode of emplacement. Overlying beds (units 5, 6, 7 and 8) indicate that deposition in relatively shallow water was taking place. If the deep-water environment persisted until unit 4 was deposited, turbidity currents or slumping would have to be postulated for unit 2.

2. Cliff erosion may have contributed carbonate boulders to sediments deposited in a littoral environment. Cliff formation by faulting must be assumed in

this hypothesis, since no evidence of a cliff shoreline has previously been found. The depositional environment would have changed from deep to shallow water prior to faulting and deposition of unit 2. Beds overlying unit 4 would have been deposited in a near-shore environment after erosion of the cliffs. It would be expected in this case that bedded carbonates should underlie the boulder conglomerate. This was not found.

If the section at Cairngorm Mountain is a close approximation of the stratigraphic thickness of the upper member, at that locality, then it must be assumed that the depositional environment varied greatly from one locality to the next. The problems of source terrain, mode of transportation and depositional environment of the upper member should be approached by more regional mapping. It is hoped that future work may elucidate these problems.

STRUCTURE

Introduction

The Precambrian rocks in the Jasper area lie within the Pyramid Mountain thrust sheet. Mountjoy (1961, sheet 2), mapping to the northwest, indicated that the Pyramid thrust dies out in that direction. Therefore, movement along the thrust was rotational, in a counter-clockwise sense. The incompetent Precambrian strata have been folded into a series of relatively tight anticlines and synclines, whereas the Jasper Formation and Formation A, comprising the competent Gog Group, have been deformed into open folds.

The discussion on structure will be confined to the Virl Lake and Saturday Night Lake map-areas.

Folding

The general trend of folds changes from N 40° W at Tekarra Creek, to N 80° W at Marjorie Lake, to N 60° W near Virl Lake. A part of the Iris Lake anticline was studied in detail because a number of consecutive beds could be traced directly around the crest of the fold. If bedding thickness in the limbs is taken as a basic measure, the arenaceous beds are 20 per cent and the argillaceous beds 100 per cent thicker in the axial region (Fig. 9). This indicates that the argillaceous units form similar folds, whereas the arenaceous units tend to fold concentrically. Since bedding attitudes within one limb of a fold remain relatively constant, the overall fold pattern is of the similar type.

Axial planes, in the Virl Lake area, are essentially vertical. Direct plunge measurements along Muhigan Creek anticline show that the fold plunges 12 to 16

degrees northwesterly throughout most of the area. In the southern part, east of the tunnel (Fig. 3), the fold plunges 12 degrees to the southeast. South of the Miette River, cleavage-bedding intersections indicate a 10 degree, northerly plunge. The Iris Lake anticline, south of Dorothy Lake, plunges 35 to 45 degrees westerly; the plunge increases to the west. A number of overturned folds were mapped in the Saturday Night Lake area (Fig. 4). The limbs dip southerly 40 degrees to 50 degrees overturned.

In the Virl Lake area the horizontal distance between the axial planes decreases from southeast to northwest. This is accompanied by a decrease in the structural relief, rather than tighter folding (Fig. 5). The decreasing structural relief may mean two things: crustal shortening by faulting in the northwestern part, or counter-clockwise rotational movement on the thrust fault.

Two anticlinal sets of cross-folds were mapped in the Virl Lake area: one in the extreme eastern part, the other southeast of Virl Lake (Fig. 3). The axial surface, of the latter set, seems to connect an off-set in the Virl Lake syncline. The structural relief of the cross-folds is probably very low (Fig. 5). The cross-fold trends N 60° W, whereas the Muhigan Creek anticline and the Virl Lake syncline trend N 40° W, in this locality. The cross-fold in the eastern part of the area trend N 30° W compared to the trend of the Virl Lake syncline, in this area, of N 60° W. The plunge of the cross-fold is 45 to 50 degrees in a southerly direction. The structural relief is less than 1000 feet. The junction of the axial planes of the cross-syncline and the Iris Lake anticline is faulted (Fig. 3).

The cross-folds connect major folds that are slightly off-set only where the competent-incompetent ratio is low. If the ratio is high, fracturing would probably take place.

Faulting

A fault in the eastern part of the Virl Lake area was inferred from the outcrop pattern and the attitudes of adjoining beds (Fig. 3). The fault strikes in a northerly direction; dip direction or degree of inclination are not known. Since the fault is located at the junction of the axial planes of the Iris Lake anticline and a cross-fold, it does not reflect the regional stress ellipsoid orientation, but rather a local stress field.

Another fault between Minaga Creek and the tunnel, along the Canadian National Railway grade shows normal-type displacement in one arenaceous unit. This unit is over- and underlain by thick argillaceous units. Argillaceous and arenaceous beds in the hanging-wall block are overturned. This fault is probably caused by gravity slumping after erosion of the Miette River valley.

West of Geikie Station (Fig. 2), a normal-type fault repeats the Miette-Old Fort Point contact (Charlesworth, personal communication, 1963). Normal faulting cannot be readily explained in a regional stress field that caused folding and thrust-type faulting. However, this may be an indication of the rotational movement on the Pyramid thrust, causing a local stress field favouring normal-type faulting.

In the Saturday Night Lake area (Fig. 4) a series of beds were assigned to the upper member since dolomite-boulder conglomerate and bedded limestone, present in this sequence, have only been found in the upper member at other localities. This posed the problem of proximity of these beds to the Old Fort Point Formation, which outcrops in the core of the Jasper anticlinorium (Fig. 4). The stratigraphic interval between the two outcrops is not sufficient to accommodate the lower and most of the upper member. During the process of mapping the area, it was found that at some localities an abrupt change from greenish to brownish grey color in the arenaceous beds

occurred between closely spaced outcrops. This abrupt color change is not characteristic of the lower member. A fault was, therefore, inferred. This did not solve the problem entirely, since the basal argillites of the upper member are non-existent in this area. A second fault as a branch of the first was postulated. The color-change boundary indicates that the faults strike northwest and dip to the northeast. The dip of the faults and probably movement along them seems to be opposite in direction to that of the Pyramid thrust. If the Pyramid thrust steepened towards the surface in this vicinity, the faults could be compared to antithetic faults in normal-type faulting. A compressional stress, perpendicular to the strike of the fault, could have built up in the thrust sheet, and may have been released by northerly dipping faults. Present information indicates that the Pyramid thrust fault flattens near surface. The attitude now observed on the fault, may be the result of late-stage folding (Röder, 1960, p. 587).

Jointing

Jointing is a very common feature in the arenaceous beds of the Miette Formation. Generally joints appear to be less evenly spaced and less continuous in graded beds than in beds with a constant grain size. This, however, was not tested statistically. Previous workers (Remington, 1960; Stauffer, 1961; Griffiths, 1962; and Steiner, 1962) plotted all field measurements on polar diagrams, and by various statistical means established significant sets and systems of joints. These were divided into extension or shear fractures on the basis of orientation and field relationships. This method has the disadvantage that the frequency and not the prominence or the continuity of the joints determines the maxima on the polar diagram.

In this study, the writer has attempted to use a more qualitative approach to the interpretation of joints. It was intended to establish all possible joint sets in

a single, well exposed fold, and using stereographic projections, to attempt an interpretation of these sets based on their attitude, continuity and prominence in outcrop. Field measurements were confined to that part of the Iris Lake anticline directly south of Dorothy Lake. This anticline showed a number of desirable features: continuous outcrop near the axis, well jointed arenaceous beds, and an absence of minor folds and faults. Two disadvantages were the plunge (35 to 45 degrees westerly) and the proximity of all outcrops to the axial region of the fold.

The poles to all joint sets were plotted on three stereographic projections (Fig. 10)[8]: (A) field measurements; (B) poles, after rotation of the fold axis into the horizontal; and (C) poles, after rotation of bedding into the horizontal, about the fold axis. The direction of the maximum principal stress axis was arbitrarily drawn perpendicular to the fold axis, as a first interpretation. Seven distinct joint sets grouped into 4 systems can be related to those described by de Sitter (1956, p. 132).

System <u>1</u> joints are continuous in outcrop and widely spaced. They are cut and frequently displaced by all joints that intersect them. Set <u>1a</u> (N 64° E/40° NW) joints were measured in the axial region and on the north limb; set <u>1b</u> joints (N 20° W/60° W) were measured in the axial region and on the southwest limb. Some set <u>Ib</u> joints show gash veining that is confined to the axial region. System <u>1</u> is, probably, a very early shear system formed before or in the early stages of folding (Hoeppener, 1953, p. 135). After rotation of the fold axis and bedding into the horizontal (Fig. 10C), set <u>1a</u> (N 51° E/vertical) and set <u>1b</u> (N 06° E/77° W) joints indicate a direction of the maximum principal stress axis of N 30° E before folding.

System <u>2</u> consists of shear-type joints which cut and locally displace system <u>1</u> joints. In some outcrops system <u>2</u> joints are cut by other joints. Joints belonging to this

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(8) Circles used in representing joint sets in Figure 10 do not indicate a radius of confidence, but are drawn to include all poles of joint sets similar in attitude and field relationships. Sets falling into the region of overlap between circles can be differentiated by their dependence on bedding attitude or plunge (cf. A, B and C; Fig. 10).

system are quite continuous and widely spaced; some are veined locally. Set 2a (North/81° E) and set 2b (N 60° E/68° SE) indicate a direction of the maximum principal stress axis of N 30° E. This system probably formed continuously throughout folding.

System 3 joints are confined to the axial region. The joints are usually short; some veining was found locally. Set 3a (N 40° W/70° NE) and set 3b (West/ vertical) are shear joints which cut and displace system 2 and 1 joints, and are locally displaced by system 2 joints. When the fold axis is rotated into the horizontal (Fig. 10 B), set 3a (N 33° W/85° NE) and set 3b (N 83° W/72° N) indicate that the maximum principal stress axis was parallel to the fold axis (N 60° W). This could be interpreted as local compression, in a depression of the fold axis.

Set 4 joints are wide gash veins confined to the axial region; they are perpendicular to the fold axis (cf. A and B, Fig. 10). This set was probably formed under local tensile stress, in a culmination of the fold axis.

These are the only joint sets that could be related to the general and local stress ellipsoid in the area and the fold, particularly. The remaining joints (Fig. 10) could not be interpreted by this approach.

Cleavage

Cleavage is prominent in all argillaceous beds, but is common only locally in the arenaceous beds. Where competent beds, such as siltstone or sandstone, are found in contact with argillite, refraction of cleavage towards the bedding-normal occurs in the competent beds (Plate IX). Cleavage planes in argillite are usually spaced less than 1 millimeter apart and are smooth and straight; in the competent beds, cleavage planes are spaced more than 3 millimeters apart and are usually hackly. The strike of cleavage in incompetent and competent beds is parallel within reading error,

but dips differ by 30 to 40 degrees. The steeper dips are always found in argillite. Two examples of curved cleavage were found along the railway grade in the southwest limb of Muhigan Creek anticline. Both are in graded beds (coarse sand to argillite) which are underlain by argillite (Plate IX). Refraction of cleavage at the base of the graded beds is similar to that described above. Within the beds, however, cleavage curves upwards until it parallels the cleavage in the argillite. The writer is of the opinion that cleavage in incompetent and competent beds is genetically the same. A single term (e.g. "schistosity", Bonorino, 1958) should be adopted to describe cleavage (cf. Billings, 1954, pp. 337-339). Cleavage was probably formed perpendicular to the maximum principal stress trajectories (Charlesworth and Evans, 1962; Bonorino, 1958). Competent beds tend to deflect the regional stress through the beds, whereas this effect is less pronounced in incompetent, argillaceous beds.

The axial plane of the Iris Lake anticline was established from bedding attitudes. The attitudes were plotted on a stereographic projection and the plane bisecting the angle between the limbs was taken as the axial plane (N 60° W/vertical). Cleavage, however, did not parallel this plane (Fig. 9). If the axial plane parallels cleavage in argillite, it should have an attitude(9) of N 60°W/ 15-20° N. This suggests that the maximum principal stress axis was inclined to the horizontal. Iris Lake anticline would then be symmetrical in space, but assymmetrical in respect to the stress ellipsoid. It is interesting to note that Griffiths' (1962, Fig. 8) detailed study of one syncline in the Wynd map-area indicates a northerly dipping axial plane, which was assumed to parallel "slaty" cleavage.

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(9) Outcrop of argillite is limited, and there are not enough readings to establish convergence or divergence of cleavage in the axial region. As an approximation cleavage is considered to be parallel.

METAMORPHISM AND VEINING

Stauffer (1961, pp. 53-58) and Griffiths (1962, pp. 49-50) gave a detailed description of the effects of metamorphism on rocks belonging to the lower member. Their data and the writer's observations are included in this discussion.

Albite was the only stable feldspar in the lower member during metamorphism. Grains of fresh feldspar and of a mixture of feldspar, sericite and chlorite indicate that feldspar of more than one composition was present in the detritus. In the arenaceous units of the upper member, both potash and sodium feldspar are present as fresh and partially altered grains. This indicates that both feldspars were relatively stable in the upper member during metamorphism. Quartz was stable, but matrix replacing the edges of quartz grains has been reported in the lower member. Calcite, siderite and chlorite were stable throughout metamorphism. The heavy minerals, which show no overgrowths, were probably metastable. Chlorite and sericite are present as the stable products of reconstituted matrix and unstable biotite. This assemblage is characteristic of the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1960, p. 534).

Veins are composed of quartz with minor amounts of chlorite and calcite. Albite was found locally. Frequently, euhedral quartz crystals can be observed in veins; at one locality (set 4, Iris Lake anticline) a quartz crystal with a 3 inch wide prismatic face, was found. Veins containing calcite, only, are abundant in the dolomite boulders of unit 4, in the upper member.

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APPENDIX

Section A. Basal part, lower member, Miette Formation; Yellowhead Highway, 1/2 mile east of mouth of Muhigan Creek 118°11'W, 52°52' N).

Height above base (feet)	Thickness (feet)	Description
	min. 30	Overlying beds; sandstone, pebbly, light greenish grey.
730	67	Argillite, silty, greenish grey, dark grey laminations; weathers rusty brown.
663	3	Sandstone, coarse grained, pebbly, light greenish grey.
660	110	Argillite, greenish grey; 10% interbedded sandstone, greenish grey, bedding thickness 5 feet.
550	33	Covered, argillite (?).
517	2	Sandstone, coarse grained, greenish grey.
515	105	Argillite, poorly exposed, weathering rusty brown.
410	5	Sandstone; graded beds, conglomerate to coarse sand, light greenish grey.
405	165	Argillite, poorly exposed; few thin sandstone and conglomerate beds.
240	6	Sandstone, fine grained, thin-bedded.
234	14	Argillite, greenish grey; laminated; weathers rusty brown.
220	54	Sandstone, greenish grey; graded beds, conglomerate to argillite, bedding thickness up to 3 feet.
166	87	Argillite, greenish grey; few thin beds of pebbly sandstone; weathers dark rusty brown.
79	79	Sandstone and quartz-pebble conglomerate, greenish grey; some graded beds; at 65 feet, 6 mm muscovite flakes.
		Underlain by Old Fort Point Formation.

Section B. Lower member, Miette Formation; southwest limb, Muhigan Creek anticline; measured along Canadian National Railway grade (118°14' W, 52°52' N).

Height above base (feet)	Thickness (feet)	Description
		Overlying beds; upper member, Miette Formation.
2214	14	Sandstone, coarse grained, pebbly, light brown; poorly indurated.
2200	110	Conglomerate, sandstone and argillite; graded beds 2-6 feet thick; medium olive grey to light brown; weathers tan.
2090	5	Conglomerate, quartz pebbles; 40% argillite fragments; brownish grey.
2085	10	Conglomerate to argillite, graded beds; brownish grey.
2075	74	Sandstone and conglomerate, light brown; some graded beds; chlorite pebbles common in most beds; thin interbeds of argillite; argillite shards at base.
2001	275	Argillite, silty, greenish grey, dark grey laminations; weathers rusty brown.
1726	47	Sandstone, coarse grained, tan; few graded beds; poorly indurated; weathers brown.
1679	36	Conglomerate to argillite, graded beds; argillite less than 10% of unit; medium grey weathers grey.
1643	19	Conglomerate, medium grey; 40% argillite fragments; weathers rusty brown.
1624	19	Conglomerate, quartz pebbles; grey.
1605	263	Covered, sandstone and argillite.
1342	47	Sandstone, coarse grained, greenish grey; 50% graded beds, conglomerate at base; weathers rusty brown.
1295	28	Conglomerate, greenish grey; some grading to coarse sand; large pyrite crystals weathered out; bedding thickness, 2-4 feet.
1267	16	Sandstone, fine grained, greenish grey; weathers brown; thin bedded.
1251	50	Conglomerate; basal 15 feet massive; remainder, graded beds, conglomerate to argillite.

Height above base (feet)	Thickness (feet)	Description
1201	116	Sandstone and argillite, interbedded; no gradation; bedding thickness, 6 inches to 4 feet. This unit forms the tunnel.
1085	3	Conglomerate, quartz pebbles; 40% argillite fragments.
1082	101	Sandstone, with conglomerate and argillite, in graded beds, bedding thickness 2-6 feet; greenish grey color.
981	44	Sandstone, coarse grained, pebbly, greenish grey; thick bedded; weathers brownish grey.
937	3	Conglomerate, quartz pebbles; 30% argillite fragments.
934	20	Conglomerate, greenish grey; thick bedded; scattered argillite fragments, throughout.
914	36	Sandstone, medium to coarse grained; bedding thickness 1-4 feet; interbedded conglomerates near top.
878	10	Argillite and siltstone; graded beds; thin bedded; load casts into overlying sandstone.
868	36	Conglomerate, quartz pebbles; few thin argillite beds.
832	25	Argillite and siltstone; thin bedded to laminated; recessive.
807	7	Sandstone; graded beds, conglomerate to argillite, repeated 4 times.
800	8	Cover.
792	63	Sandstone, coarse grained, pebbly, greenish grey; few thin argillite beds; bedding thickness 2-5 feet; weathers light grey.
729	33	Sandstone and argillite, interbedded; recessive; sandstone pebbly in some beds.
696	86	Argillite, poorly exposed; sandy in last few feet.
610	17	Sandstone, coarse grained, greenish grey; massive; basal conglomerate.
593	10	Cover, argillite (?).
583	10	Sandstone, coarse grained; massive.

Height above base (feet)	Thickness (feet)	Description
573	25	Cover; argillite, sandy; for a few feet at base and top.
548	3	Sandstone, coarse grained; basal conglomerate.
545	15	Cover, argillite(?).
530	8	Sandstone, medium to coarse grained, greenish grey; 25% argillite beds.
522	3	Conglomerate, quartz pebbles, greenish grey; weathers brown.
519	24	Cover, argillite(?).
495	5	Sandstone, coarse grained, greenish grey; massively bedded; weathers light grey.
490	12	Cover, argillite(?).
478	118	Sandstone, medium to coarse grained, greenish grey; isolated graded beds, conglomerate to sand; weathers light grey.
360	27	Argillite, silty, greenish grey; laminated; weathers rusty brown.
333	8	Paraconglomerate; quartz and argillite pebbles, pebbles, maximum size 3 cm in diameter; non-laminated, argillite matrix sand fraction is absent.
325	45	Argillite, silty, greenish grey; laminated.
280	20	Conglomerate, quartz pebbles; sandy matrix massively bedded.
260	32	Argillite, poorly exposed.
228	98	Sandstone, with conglomerate; repeated graded bedding; argillite shards common; weathered out pyrite cubes common on some bedding planes; greenish grey; weathers light grey and rusty brown.
130	12	Conglomerate, quartz pebbles; sandy matrix; massively bedded.
118	51	Sandstone, similar to that overlying conglomerate.
67	21	Argillite, silty; few thin sandstone beds.

Height above base (feet)	Thickness (feet)	Description
46	20	Sandstone, conglomerate and argillite; graded beds; bedding thickness 2-5 feet.
26	4	Argillite, silty, greenish grey; weathers grey.
22	22	Sandstone, coarse grained, pebbly, greenish grey; graded beds, fine to coarse sand; bedding thickness 3-6 feet.
		The base of the section is separated from the Old Fort Point Formation by a stratigraphic thickness of 150 feet (calculated).

Section C. Upper member, Miette Formation; measured on the north slope of Tekarra Mountain (117°58' W, 52°51' N) (Plate V).

Height above base (feet)	Thickness (feet)	Description
		Overlying beds, Gog Group; cliff forming; quartzite, conglomeratic; interbedded siltstone, argillaceous.
		Unit 8
1594	104	Argillite, silty; interbedded siltstone; sandstone, medium to fine grained, at base of graded beds; bedding thickness 1-4 inches, weathers dark brown.
		Unit 7
1490	17	Sandstone, argillaceous, medium to coarse grained, light brown near base to dark brown at top; bedding thickness 3 feet.
		Unit 6
1473	153	Argillite, silty, medium grey; sandstone, brown, at base of graded beds, in upper 50 feet; bedding thickness 1/4-1/2 inch at base to 4 inches at top; weathers dark brown.
		Unit 5
1320	13	Conglomerate, quartz pebbles, sandy matrix, light grey; weathers brownish grey.
1307	6	Conglomerate, quartz pebbles, sandy matrix; 25% argillite shards; recessive; weathers rusty brown.
1301	17	Conglomerate and sandstone, light brown, quartz and some dolomite pebbles; repeated graded bedding; bedding thickness 2 feet.

Height above base (feet)	Thickness (feet)	Description
		Unit 4
1284	32	Conglomerate, dolomite blocks from pebble size to 6 feet in diameter make up 65% of this bed; matrix, sandy, quartz-pebble conglomerate, light brown; dolomite, silty, light grey, weathers tan. Dolomite blocks criss-crossed by calcite veinlets (Plates V and VI).
1252	5	Conglomerate; sandy-argillite matrix, dark brown; quartz pebbles; some argillite shards at base.
1247	19	Conglomerate; silty dolomite blocks up to 1 1/2 feet in diameter; matrix, quartz-pebble conglomerate; 20% argillite shards.
1228	2	Argillite, silty, greenish grey; laminated; weathers medium grey.
1226	7	Argillite, silty, medium grey; interbedded sandstone, light brown, sandstone 20% of this unit; weathers rusty brown.
1219	24	Conglomerate, 30% dolomite cobbles, 15% argillite fragments; matrix, quartz pebble conglomerate, light brown.
		Unit 2
1195	10	Cover, sandstone(?).
1185	10	Sandstone, coarse grained, pebbly, light brown; few thin argillite partings.
		Unit 1
1175	1175	Argillite, bluish grey; poorly exposed.
		Underlying beds, lower member, Miette Formation.

Section D.[10] Part of upper member, Miette Formation; measured on the south slope of Cairngorm Mountain (118°11'W, 52°56' N).

Height above base (feet)	Thickness (feet)	Description
		Overlying beds, Gog Group. Sandstone, medium to coarse grained, olive green to grey; interbedded siltstone; weathers rusty brown; a competent unit.
2200	860	Argillite, silty to sandy in upper 100 feet, olive green; micaceous sheen along cleavage; slaty in lower 700 feet, thin bedded in upper part; weathers medium grey.

(10) This section was measured by Dr H.A.K. Charlesworth, Dr M. Philcox, J.L. Weiner and M. Shafiqullah (Sept. 10, 1962).

Height above base (feet)	Thickness (feet)	Description
1340	30	Argillite, silty to sandy, light grey, 30% dark grey laminations; micaceous sheen along cleavage planes.
1310	50	Cover, probably underlain by argillite.
1260	30	Sandstone; thick-bedded; 9-12 inch argillite partings.
1230	30	Cover, probably underlain by sandstone.
1200	30	Argillite; interbedded sandstone, coarse grained, pebbly, medium grey; 75% of the pebbles are sub-rounded feldspar.
1170	425	Sandstone and interbedded conglomerate, medium grey; weathered surface stained by limonite.
745	105	Sandstone, medium grey; thin argillite partings; weathered surface, limonite stained.
640	90	Argillite.
550	15	Sandstone.
535	25	Argillite, greenish grey; interbedded sandstone; weathers dark brown.
510	40	Sandstone, medium grained, pebbly in some beds, light brown; interbedded with 40% argillite, greenish grey; weather dark brown.
470	10	Sandstone and conglomerate, dark greenish grey; 10% chlorite and 15% feldspar phenoclasts; weathers medium grey.
460	50	Conglomerate, dolomite boulders and pebbles in a matrix of sandstone; argillite fragments are present throughout. Dolomite, silty, light grey, weathers tan; thin argillite partings in sandstone between beds containing dolomite boulders.
410	50	Sandstone, thin-bedded, conglomeratic in some beds, weathers dark brown; interbedded with argillite, greenish grey, micaceous sheen along cleavage planes, weathers brown.
360	360	Argillite, bluish grey; thin bedded to laminated; undulatory bedding; micaceous sheen along cleavage planes; weathers rusty brown. At 190 feet and 310 feet above the base, thin silt bands are present, the remainder of the argillite has a uniform texture.

This section did not reach the base of the upper member, Miette Formation.

Plate I

Paraconglomerate specimens from the type section in the Virl Lake map-area. Outcrop is 750 feet east of the CNR tunnel.

Argillite slab in coarse sandstone, from the type section.

Weathered cavities, originally pyrite cubes in coarse-grained, pebbly sandstone. Outcrop above the CNR tunnel.

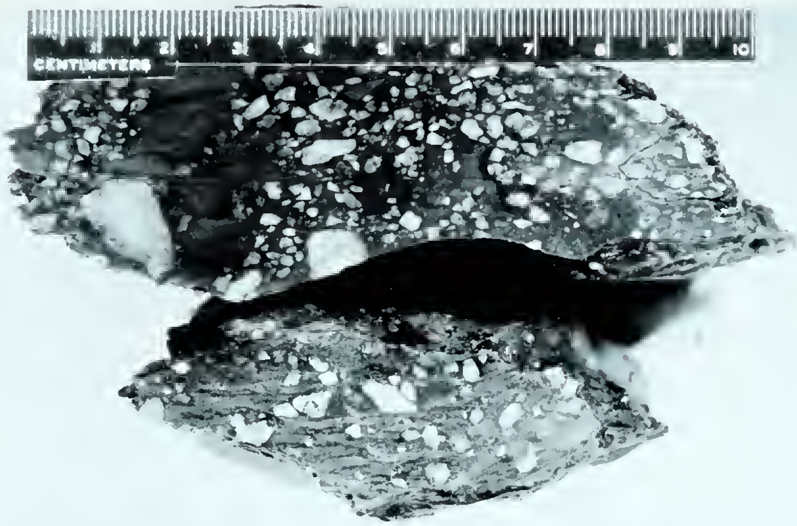
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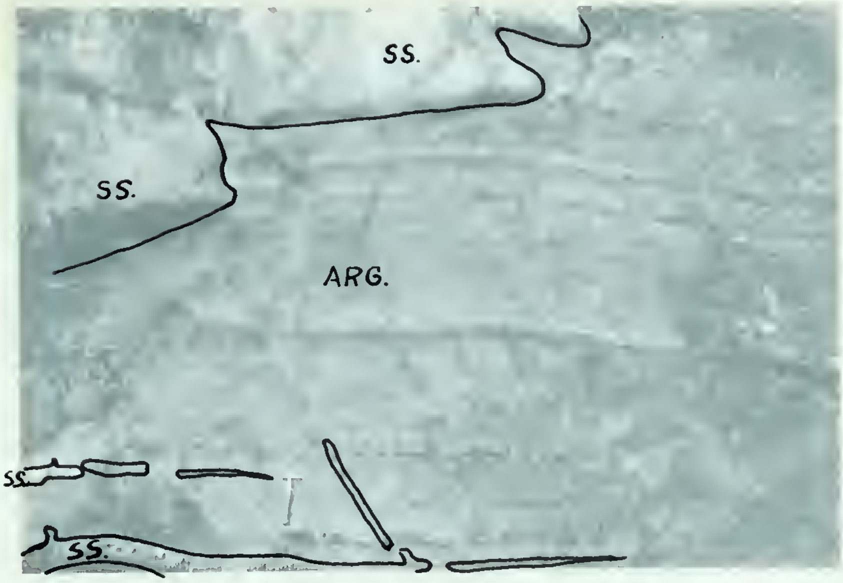
PLATE II

Multiple scour channel in the upper left hand corner; sandstone sills and dykes below. Outcrop between Dorothy and Virl Lakes (see Figs. 3 and 8).

Sandstone sills and dykes, showing the source bed at the left (cf. Fig. 8).

Detail of the oldestscour-channel-bank. The lowest sandstone is an incipient sill (cf. Fig. 8).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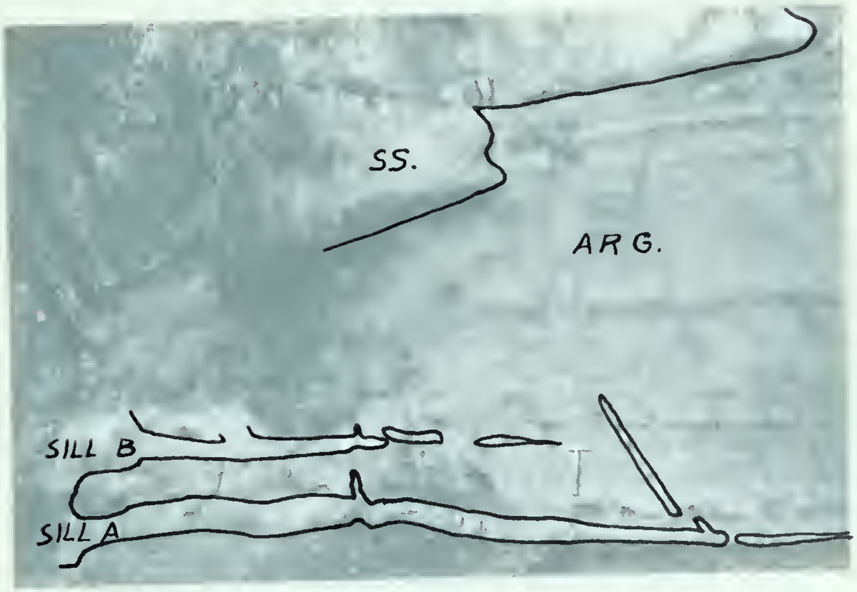
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PLATE II

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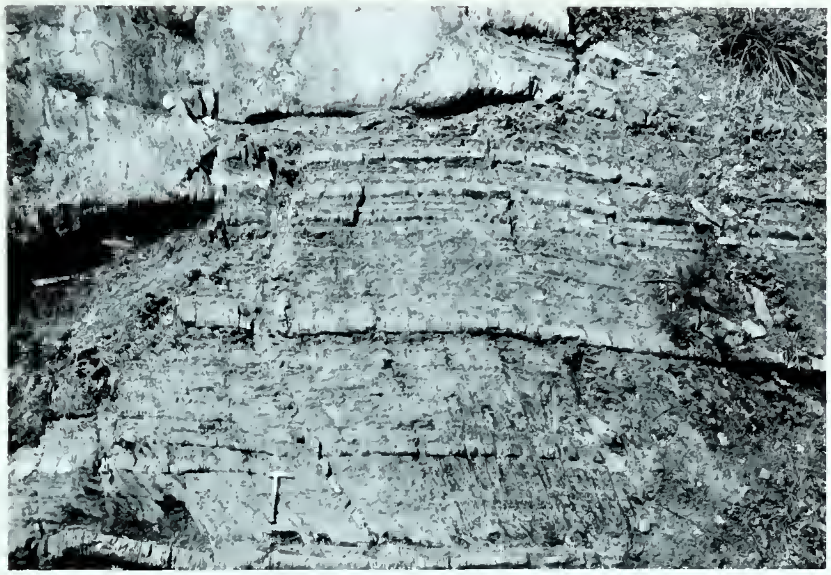
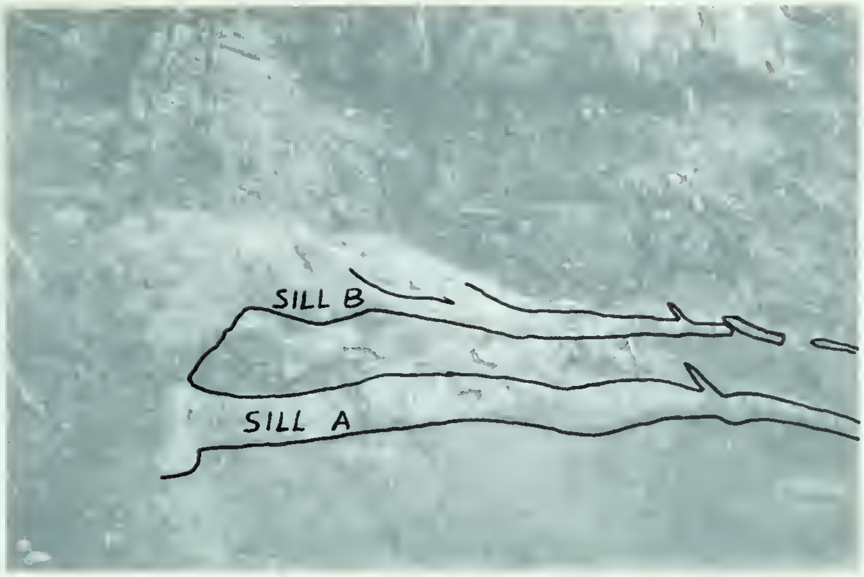


Plate III

Sandstone sills and dykes - note the discordance between the lower sill and the overlying argillite (cf. Fig. 8).

Detail of argillite bed between sill A and B. A few very small sills are outlined on the over-lay (cf. Fig. 8).

Detail of the upper part of sill B (cf. Fig. 8).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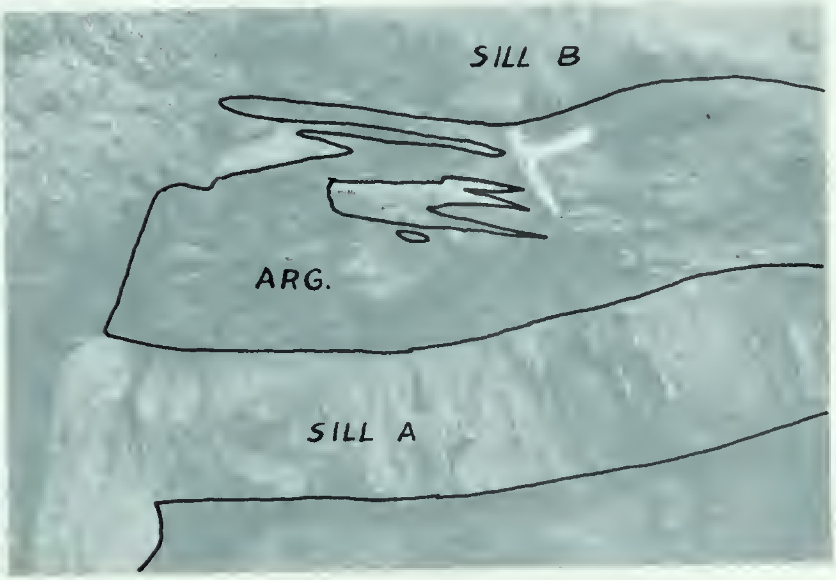
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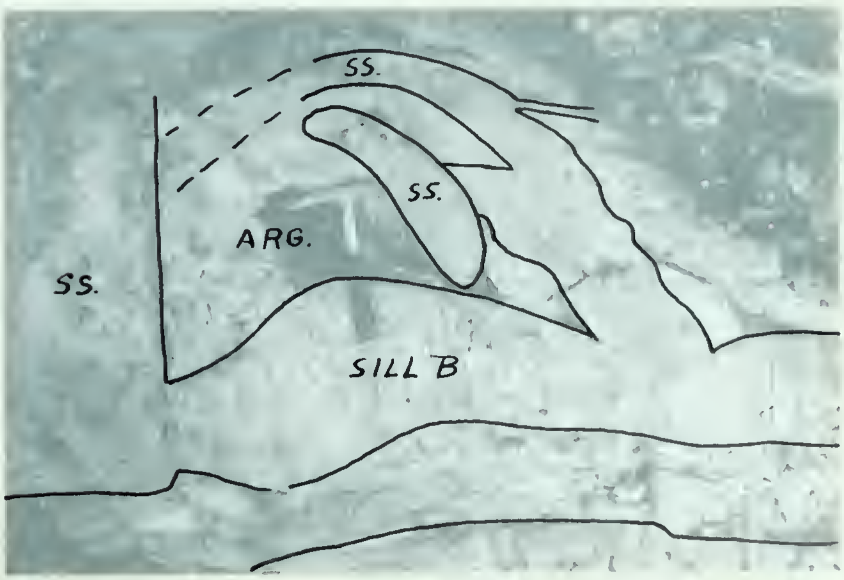
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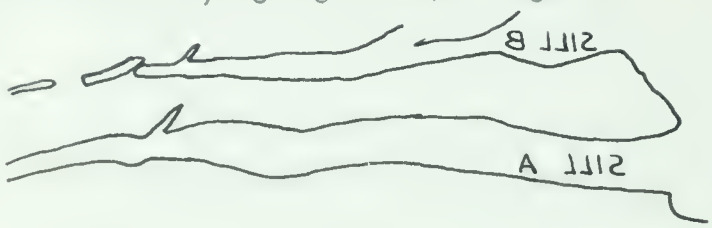
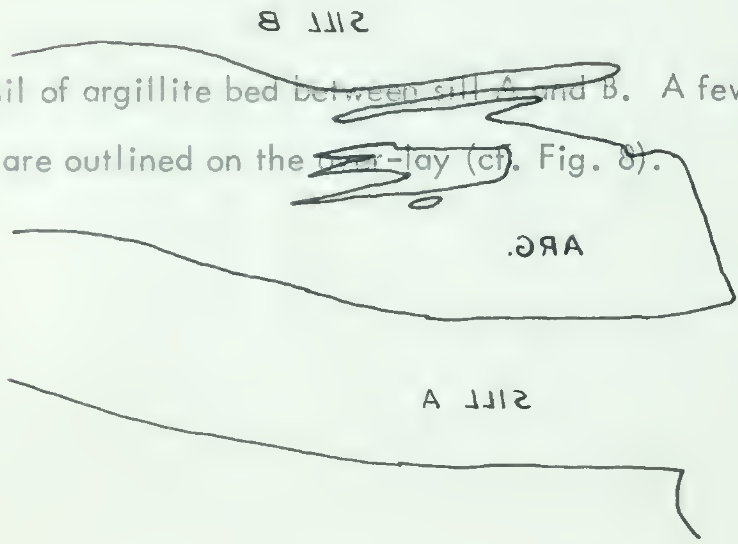
Plate III

Sandstone sills and dykes - note the discordance between the lower sill and the overlying argillite (cf. Fig. 8).



Detail of argillite bed between sill A and B. A few very small sills are outlined on the over-lay (cf. Fig. 8).



Detail of the upper part of sill B (cf. Fig. 8).

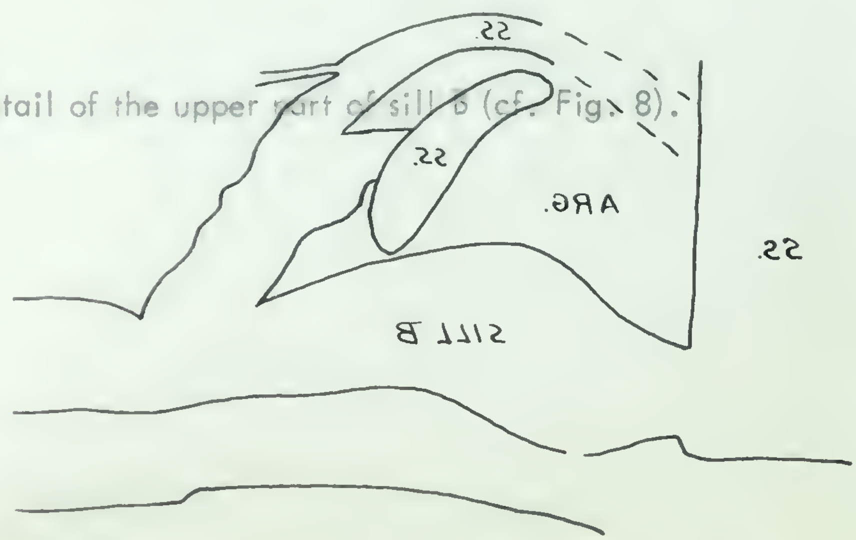


Plate IV

Graded bedding in the lower member.

Detail of a sandstone dyke originating from sill A. The dyke has been displaced by bedding plane slip in the argillite (cf. Fig. 8).

Small dykes from sills A and B. The discontinuity of sill B (upper right hand corner) interrupts the bedded argillites and, therefore, cannot be attributed to bedding plane slip (cf. Fig. 8).

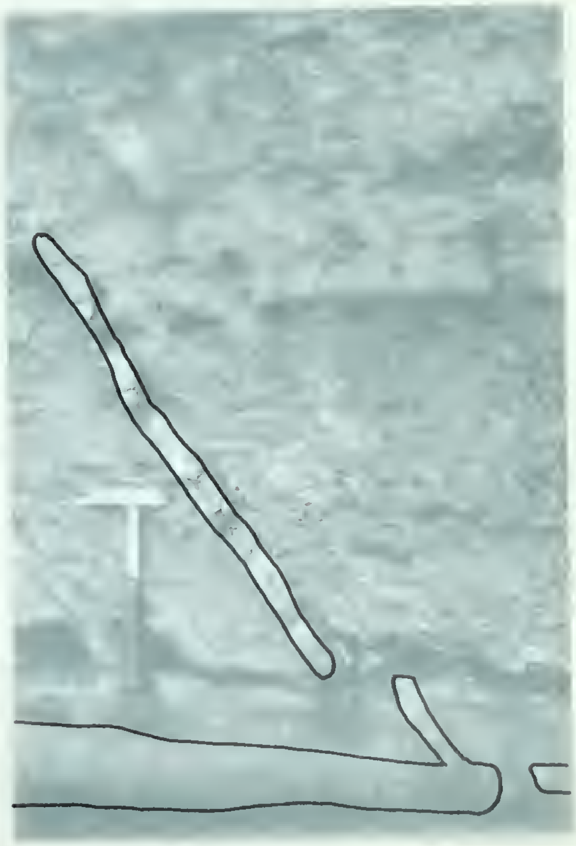
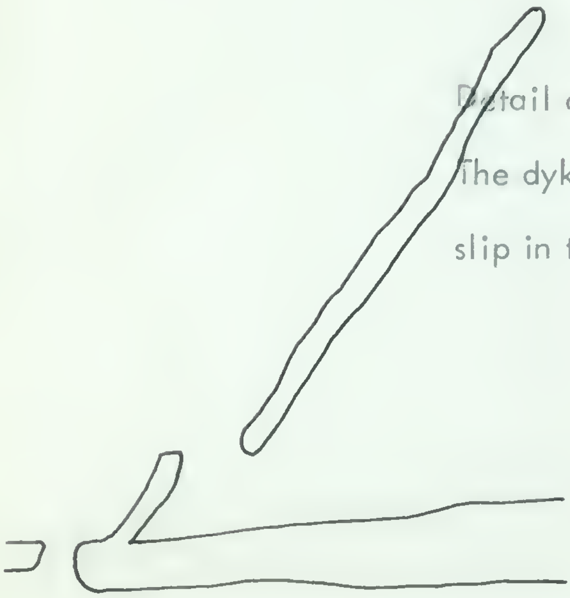
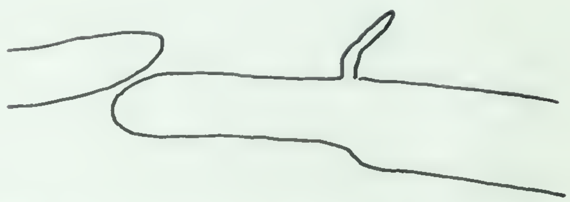


Plate IV

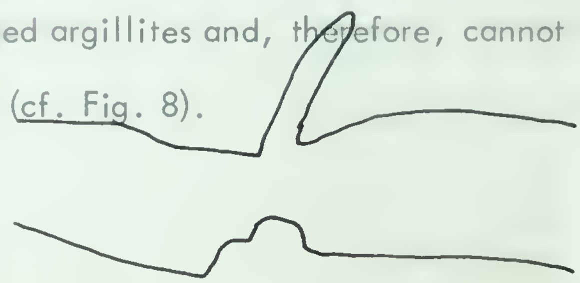
Graded bedding in the lower member.



Detail of a sandstone dyke originating from sill A. The dyke has been displaced by bedding plane slip in the argillite (cf. Fig. 8).



Small dykes from sills A and B. The discontinuity of sill B (upper right hand corner) interrupts the bedded argillites and, therefore, cannot be attributed to bedding plane slip (cf. Fig. 8).



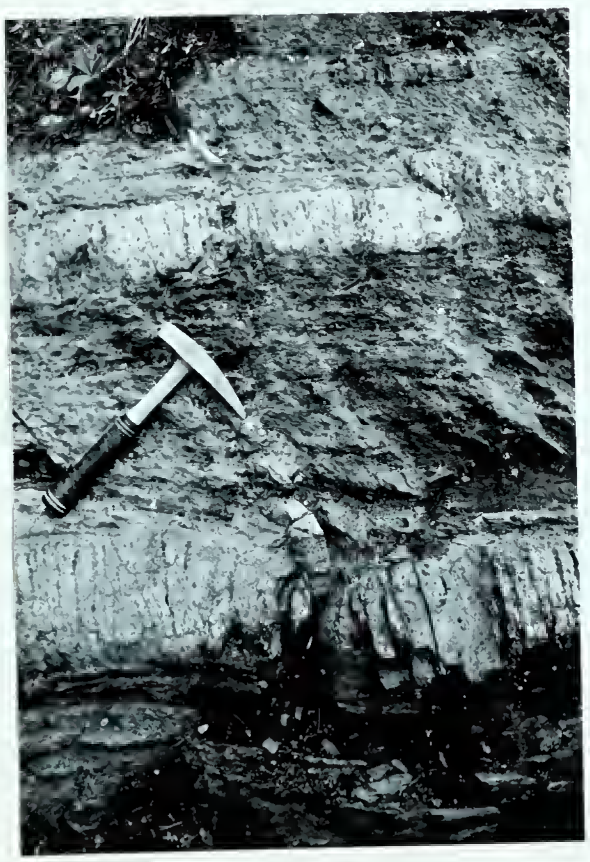


Plate V

North slope of Tekarra Mountain as seen from Signal Mountain.

Dolomite boulder conglomerate at Tekarra Mountain.

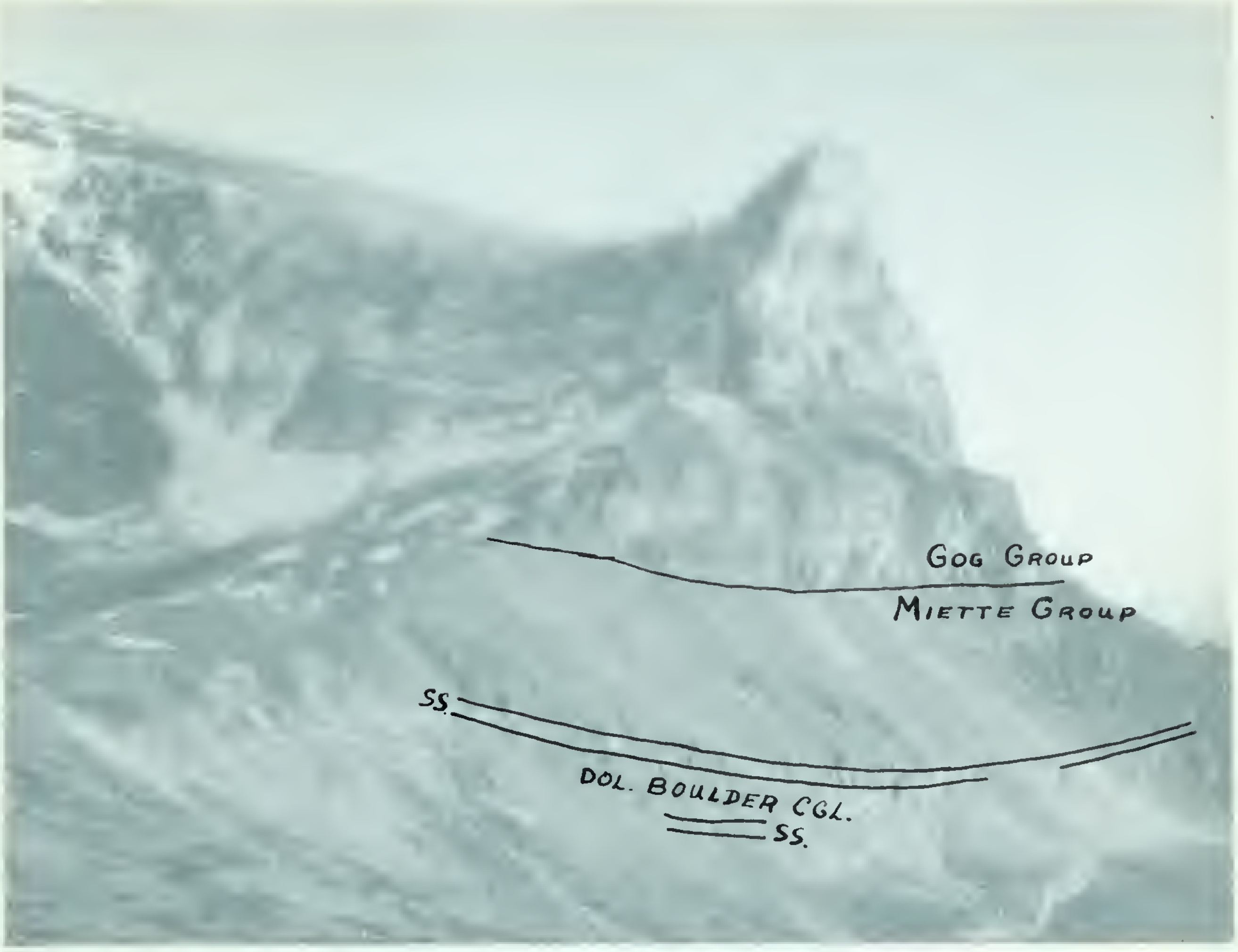

GOG GROUP
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Plate V

North slope of Tekarra Mountain as seen from Signal Mountain.

Dolomite boulder conglomerate at Tekarra Mountain.

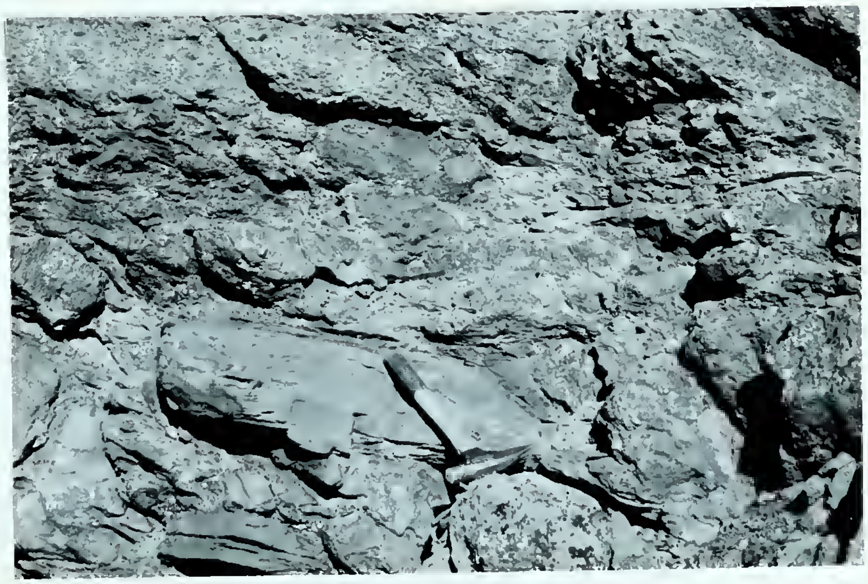
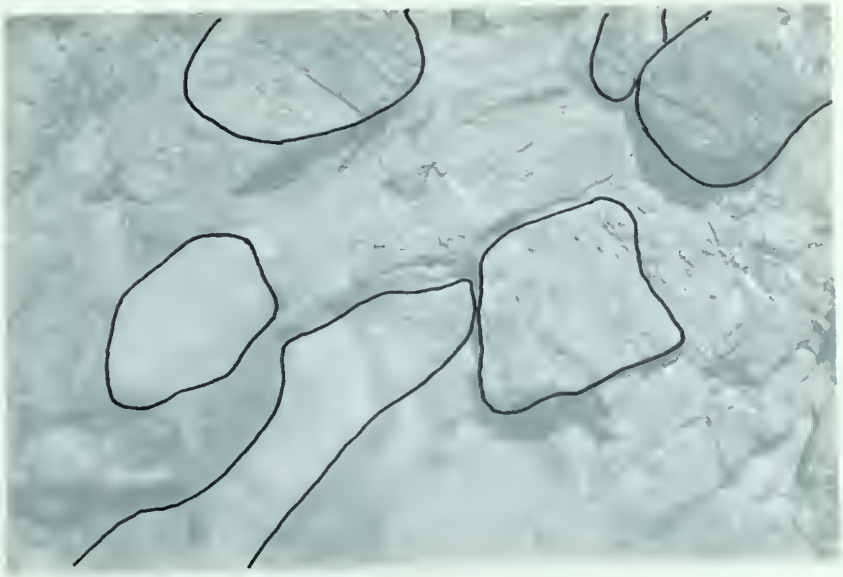


Plate VI

Argillite and silty dolomite pebbles in a quartz-pebble-conglomerate matrix. Tekarra Mountain section.

Dolomite boulders in a quartz-pebble-conglomerate matrix. Tekarra Mountain Section.

Hand specimens of the dolomite boulder conglomerate. The specimen on the left is from Tekarra Mountain; the one on the right is from Saturday Night Lake.



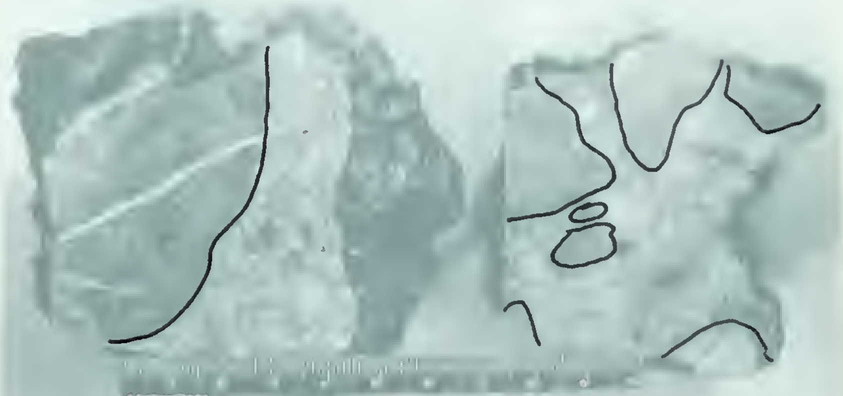
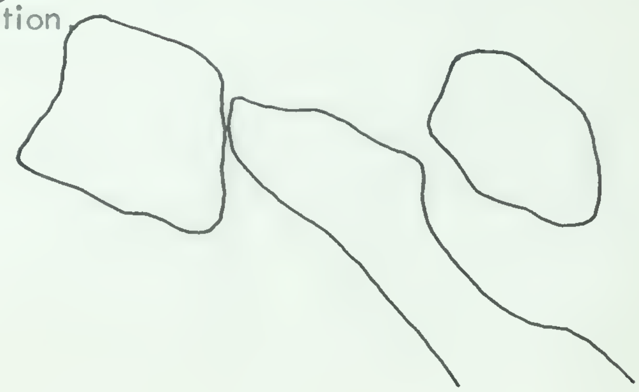


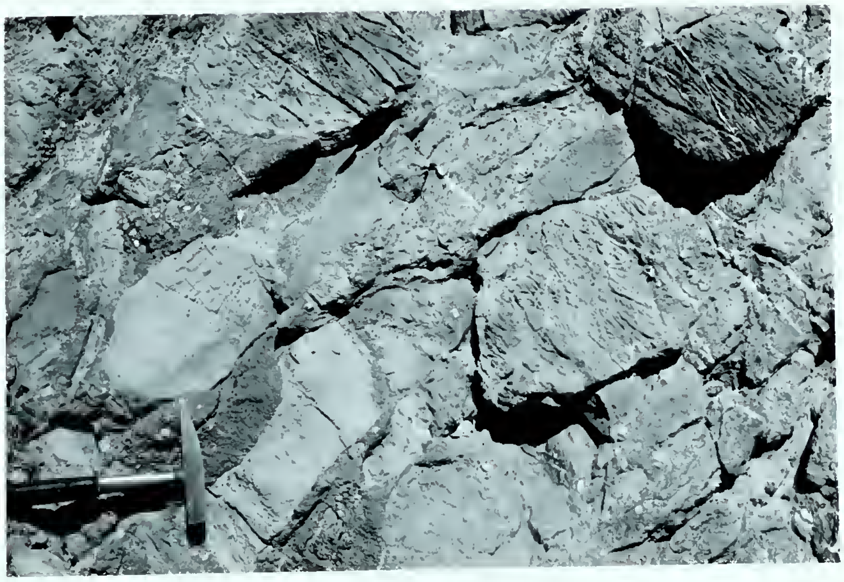
Plate VI

Argillite and silty dolomite pebbles in a quartz-pebble-conglomerate matrix. Tekarra Mountain section.

Dolomite boulders in a quartz-pebble-conglomerate matrix. Tekarra Mountain Section.



Hand specimens of the dolomite boulder conglomerate. The specimen on the left is from Tekarra Mountain; the one on the right is from Saturday Night Lake.



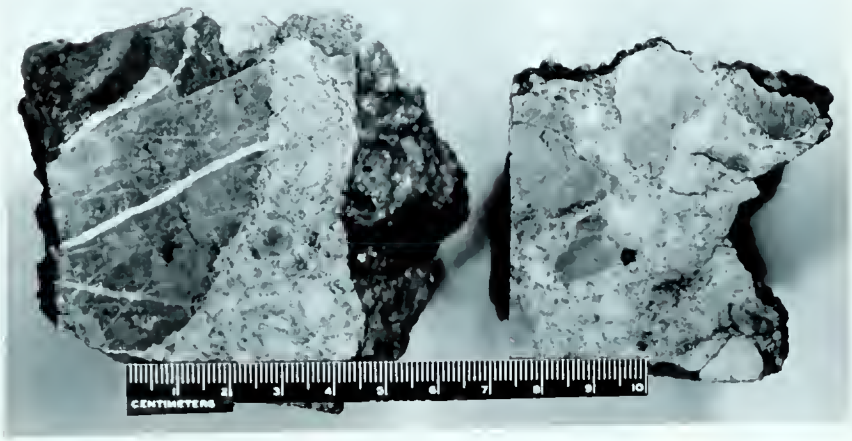
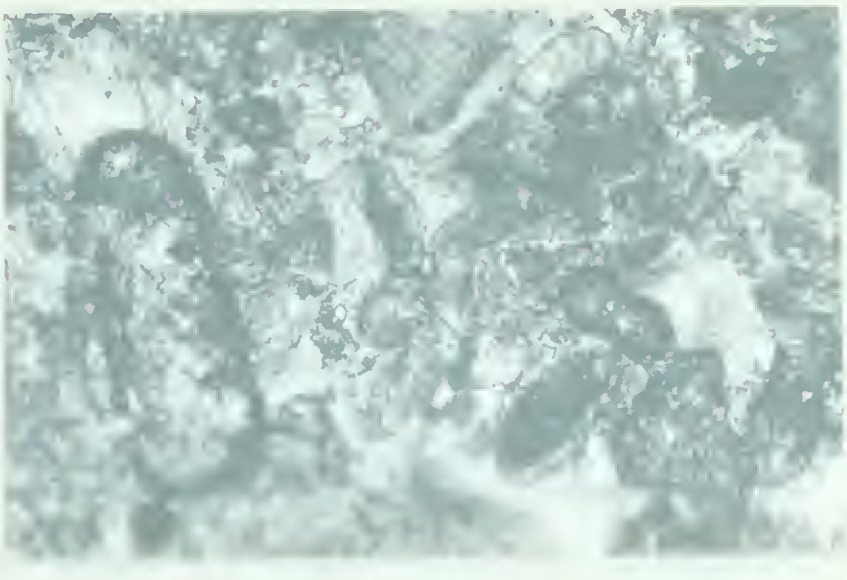

1 2 3 4 5 6 7 8 9 10
CENTIMETERS

Plate VII

Hand specimen of silty limestone--stratigraphically below the dolomite boulder conglomerate at Saturday Night Lake (see Fig. 4).

Photomicrograph of the same limestone as above.
x30.

Photomicrograph of dolomite from Saturday Night Lake. The areas outlined on the over-lay were probably vugs at one time.
x60.



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x30.

Photomicrograph of dolomite from Saturday Night Lake. The areas outlined on the over-lay were probably vugs at one time.

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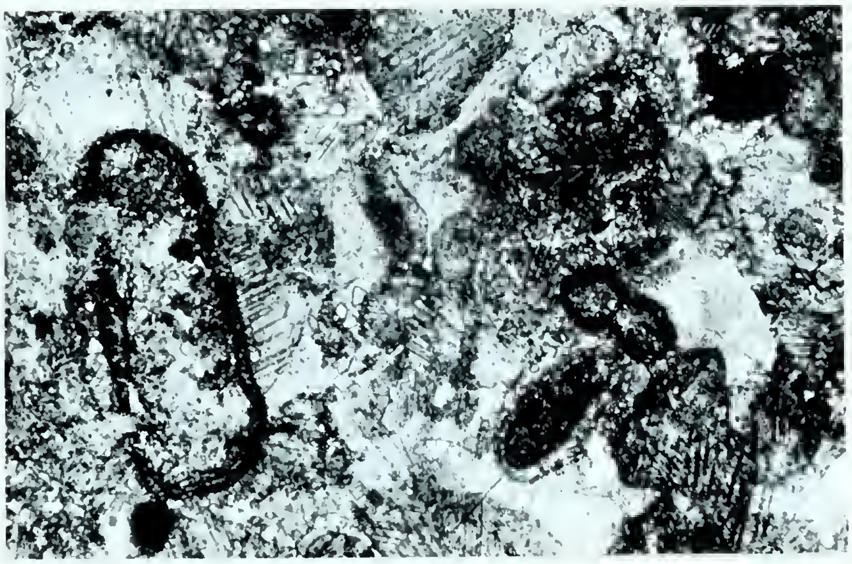


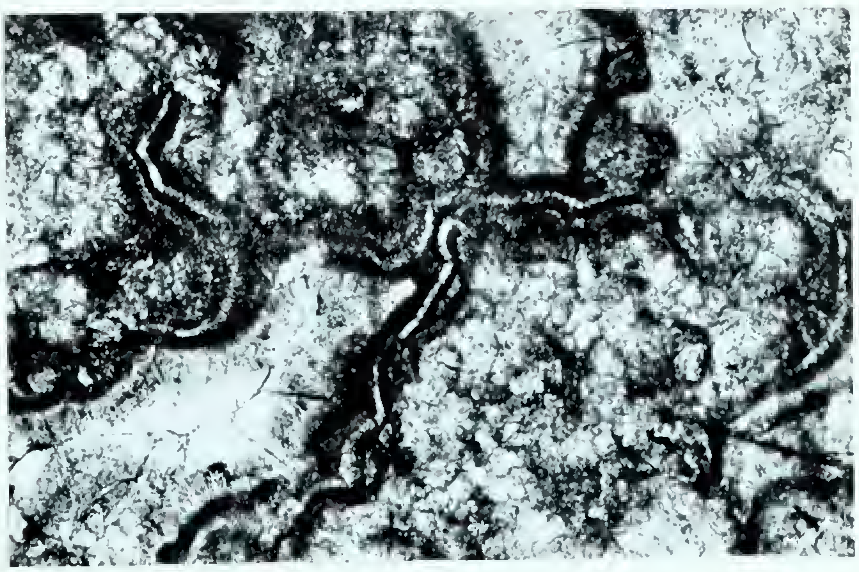


Plate VIII

Photomicrograph of dolomite from Saturday Night Lake.

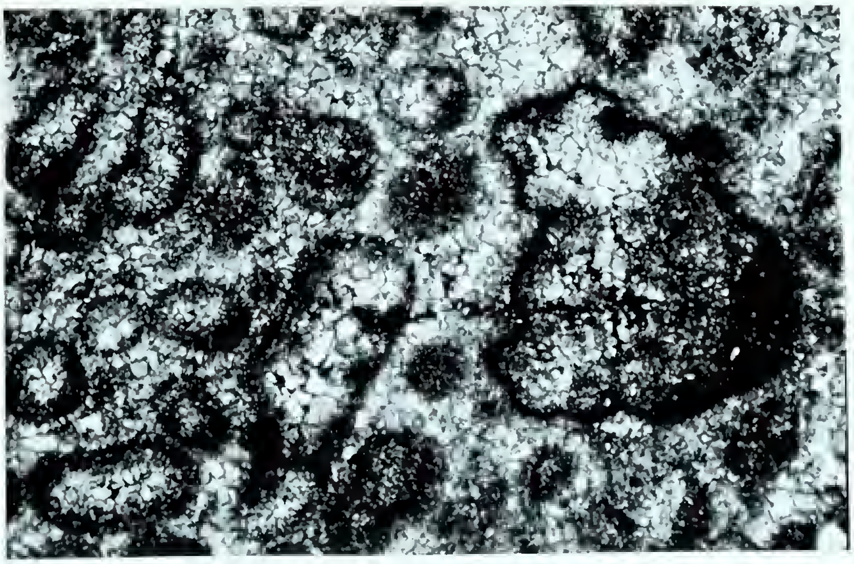
×30

Photomicrograph of dolomite from Tekarra Mountain.

×30

Photomicrograph of dolomite from Cairngorm Mountain.

×30



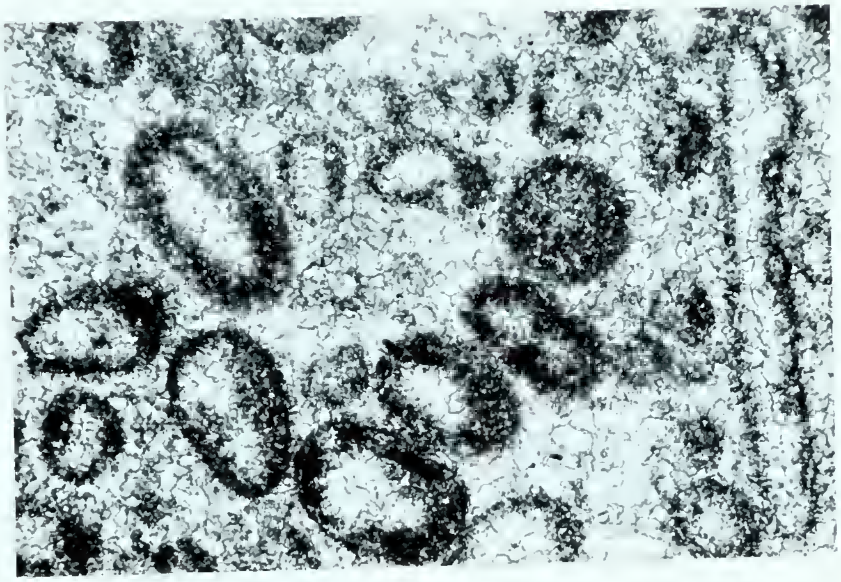


Plate IX

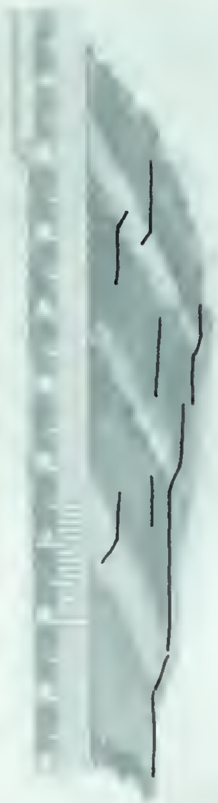
Interbedded siltstone and argillite. Cleavage is deflected at every siltstone-argillite interface. Specimen from Iris Lake anticline.

Curved cleavage in a graded bed. SW limb of Muhigan Creek anticline.

Curved cleavage in a graded bed overlying argillite. Note the deflection of cleavage at the sandstone-argillite interface. SW limb Muhigan Creek anticline.


TRACE OF AXIAL PLANE


TRACE OF AXIAL PLANE



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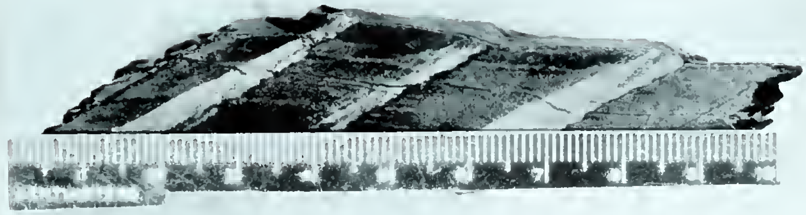
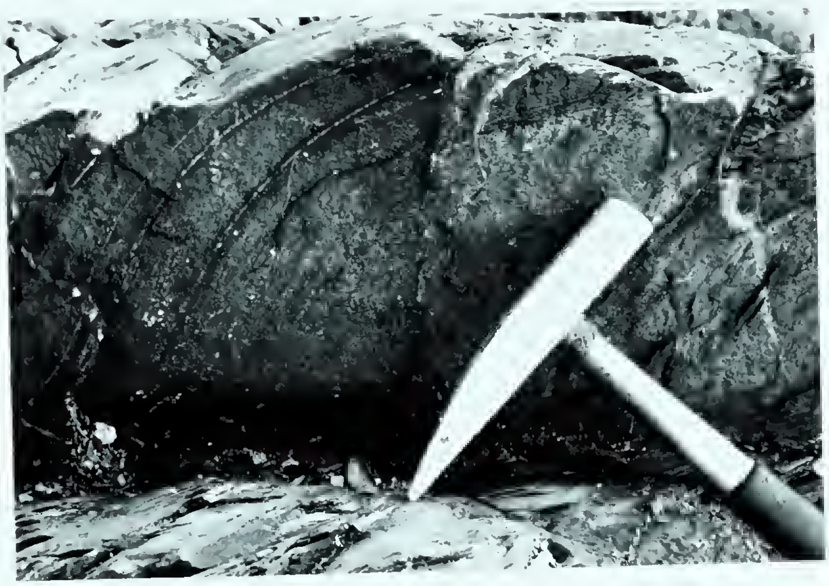




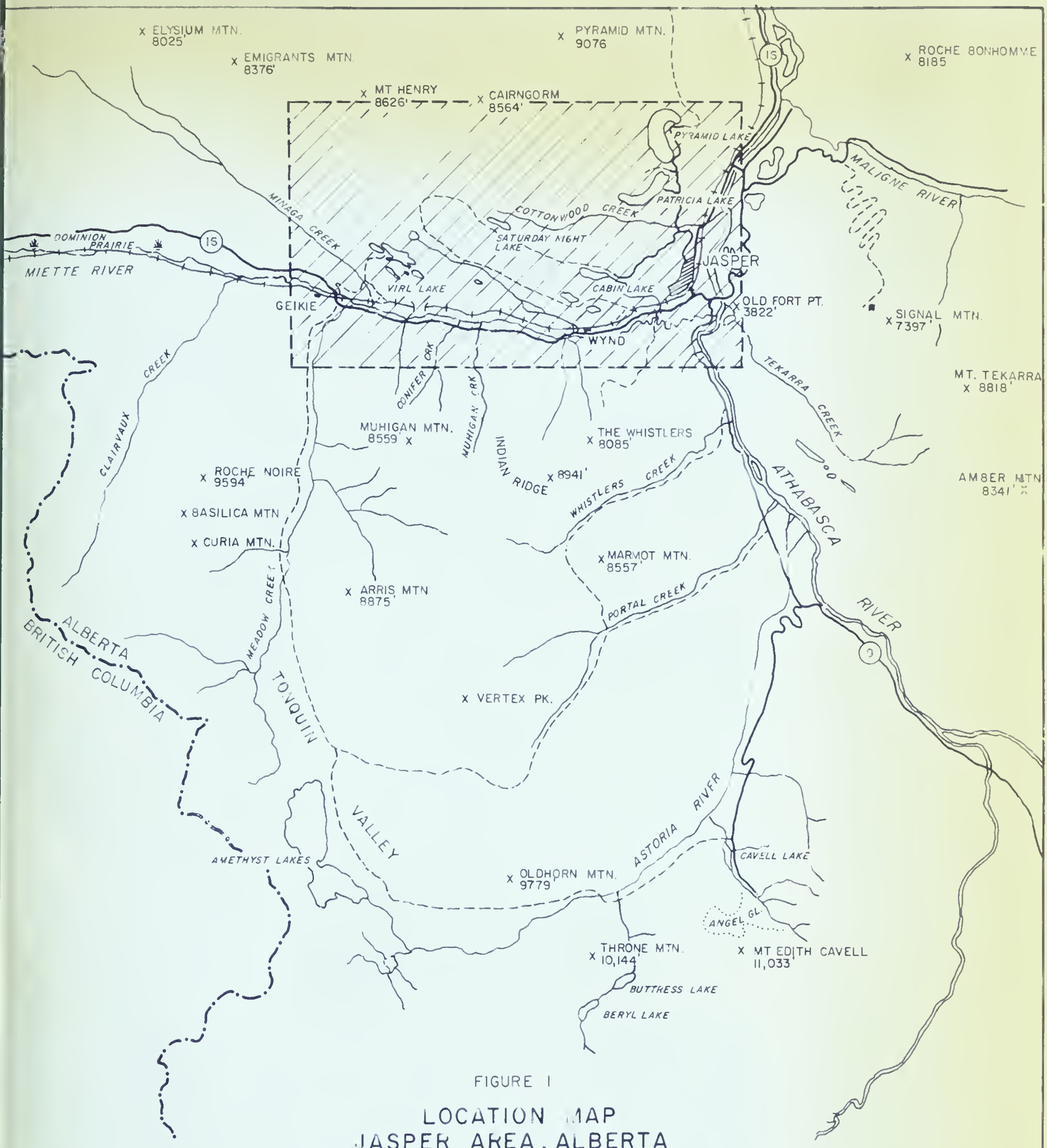


FIGURE 1

LOCATION MAP
JASPER AREA, ALBERTA

MILES

0 1 2 3 4 5 6 7 8 9 10

LEGEND

- AREA COVERED BY FIGURE NO. 2
- x 8220 LOCATION AND ELEVATION OF MOUNTAIN
- (16) HIGHWAYS AND ROADS
- ------ TRAILS
- CANADIAN NATIONAL RAILWAY

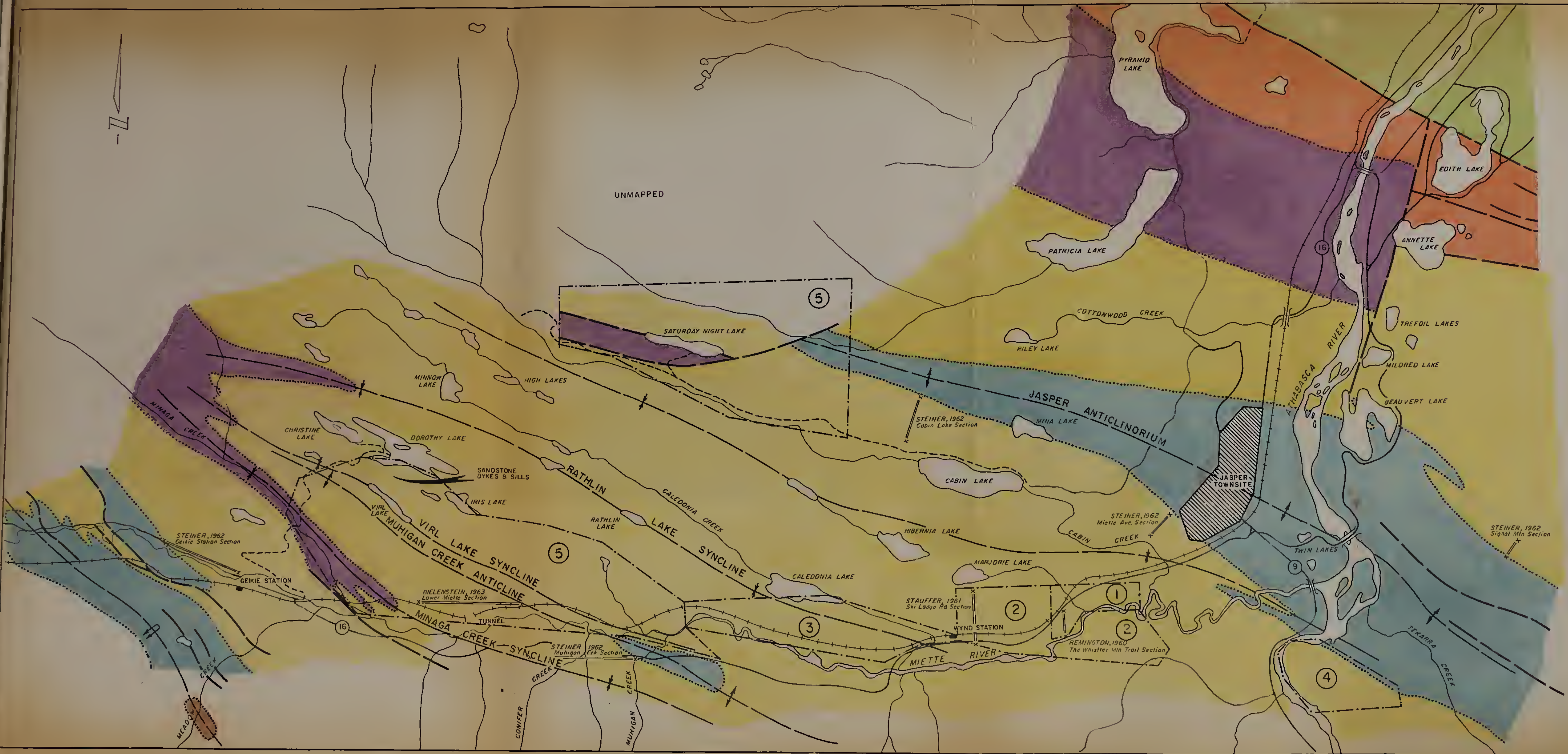


FIGURE 2

JASPER AREA
GENERAL GEOLOGICAL MAP

BASED ON MAP BY CHARLESWORTH, EVANS & STAUFFER 1961

SCALE

0 — 1 — 2 MILES

AREAS MAPPED BY

1. REMINGTON 1960 (Whistler Mountain Trail Map Area)
2. STAUFFER 1961 (Ski Lodge Road Map Area)
3. GRIFFITHS 1962 (Wynd Station Map Area)
4. STEINER 1962 (Tekarra Creek Map Area and four sections)
5. BIELENSTEIN 1963 (Virl Lake, Fig. 3, and Saturday Night Lake, Fig 4, Map Area)

LEGEND

PALAEOZOIC

UNDIVIDED

JASPER FORMATION

PRECAMBRIAN

UPPER MIETTE FORMATION

LOWER MIETTE FORMATION

OLD FORT POINT FORMATION

UNNAMED SANDSTONE

FAULT

ANTICLINE

SYNCLINE

HIGHWAYS & ROADS

CANADIAN NATIONAL RAILWAY

STATION

MEASURED SECTION

CONTACTS (APPROXIMATE)

MAP AREA

TRAILS

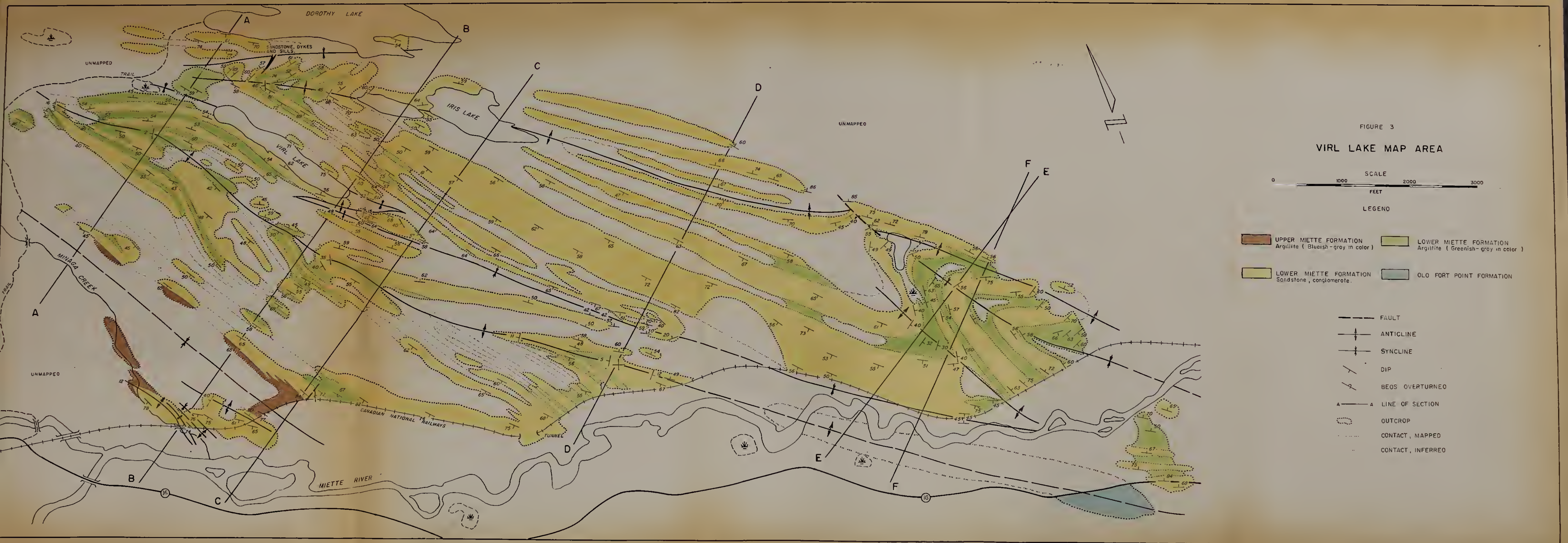


FIGURE 3
VIRL LAKE MAP AREA
SCALE
0
1000
2000
3000
FEET
LEGEND
UPPER MIETTE FORMATION
Argillite (Blueish-gray in color)
LOWER MIETTE FORMATION
Argillite (Greenish-gray in color)
LOWER MIETTE FORMATION
Sandstone, conglomerate
OLD FORT POINT FORMATION
FAULT
ANTICLINE
SYNCLINE
DIP
BEDS OVERTURNED
LINE OF SECTION
OUTCROP
CONTACT, MAPPED
CONTACT, INFERRED
DOROTHY LAKE
IRIS LAKE
VIRL LAKE
SANDSTONE, DYKES AND SILLS.
UNMAPPED
TRAIL
MINAGA CREEK
CANADIAN NATIONAL RAILWAYS
TUNNEL
MIETTE RIVER

FIGURE 4

SATURDAY NIGHT LAKE MAP AREA

SCALE

0 1000 2000 3000 4000

FEET

LEGEND

- UPPER MIETTE FORMATION Dolomite boulder conglomerate.
- LIMESTONE Black, silty
- UPPER MIETTE FORMATION OR UPPERMOST LOWER MIETTE FORMATION. Sandstone, conglomerate. (Moderate brown in color.)
- UPPER & LOWER MIETTE FORMATION. Argillite
- LOWER MIETTE FORMATION Sandstone, conglomerate (Greenish-gray color)
- OLD FORT POINT FORMATION

FAULT

ANTICLINE DEFINED AND OVERTURNED

SYNCLINE DEFINED AND OVERTURNED

DIP

BEDS OVERTURNED

WAY UP OF BEDS UNKNOWN

LINE OF SECTION

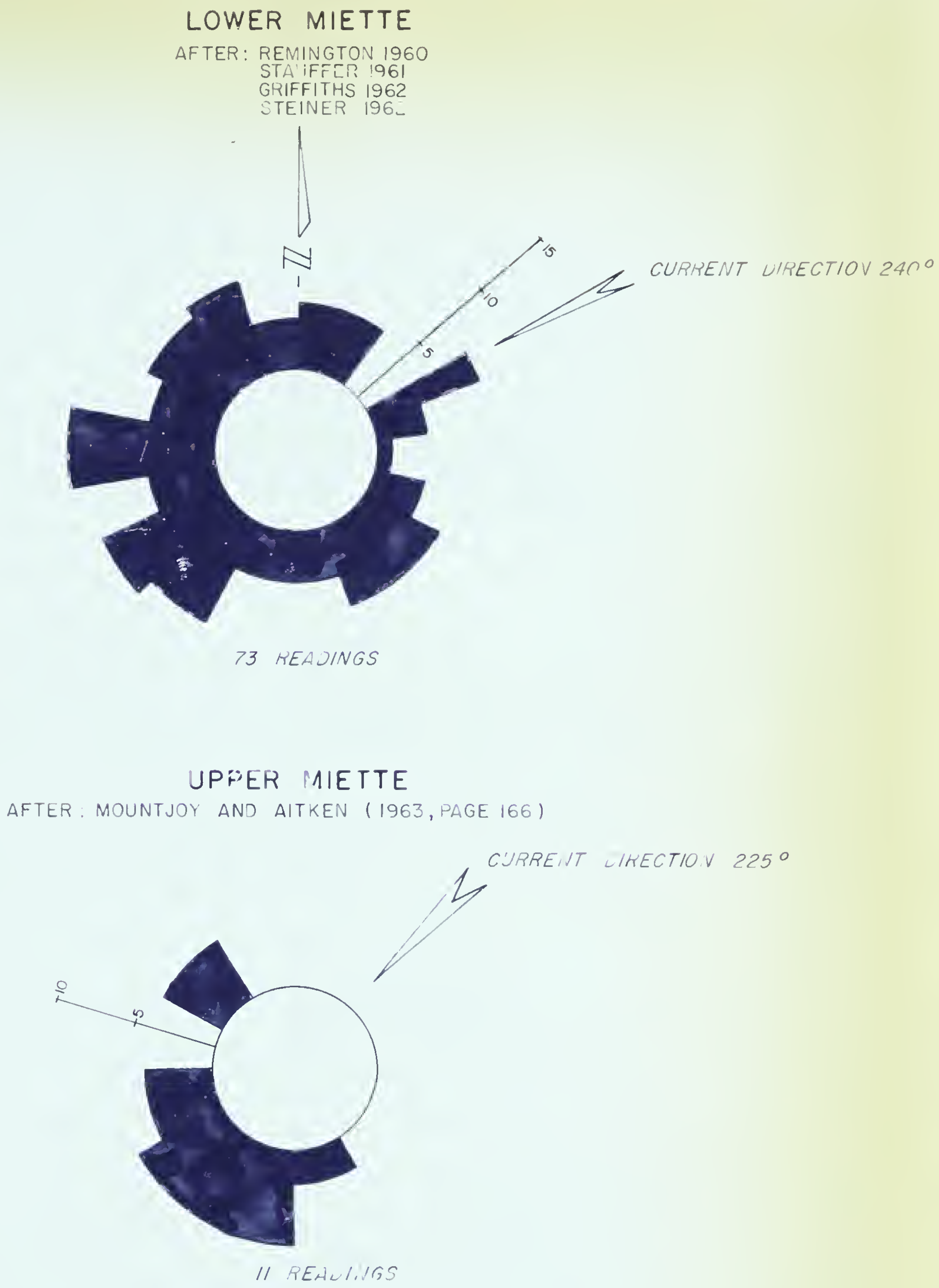


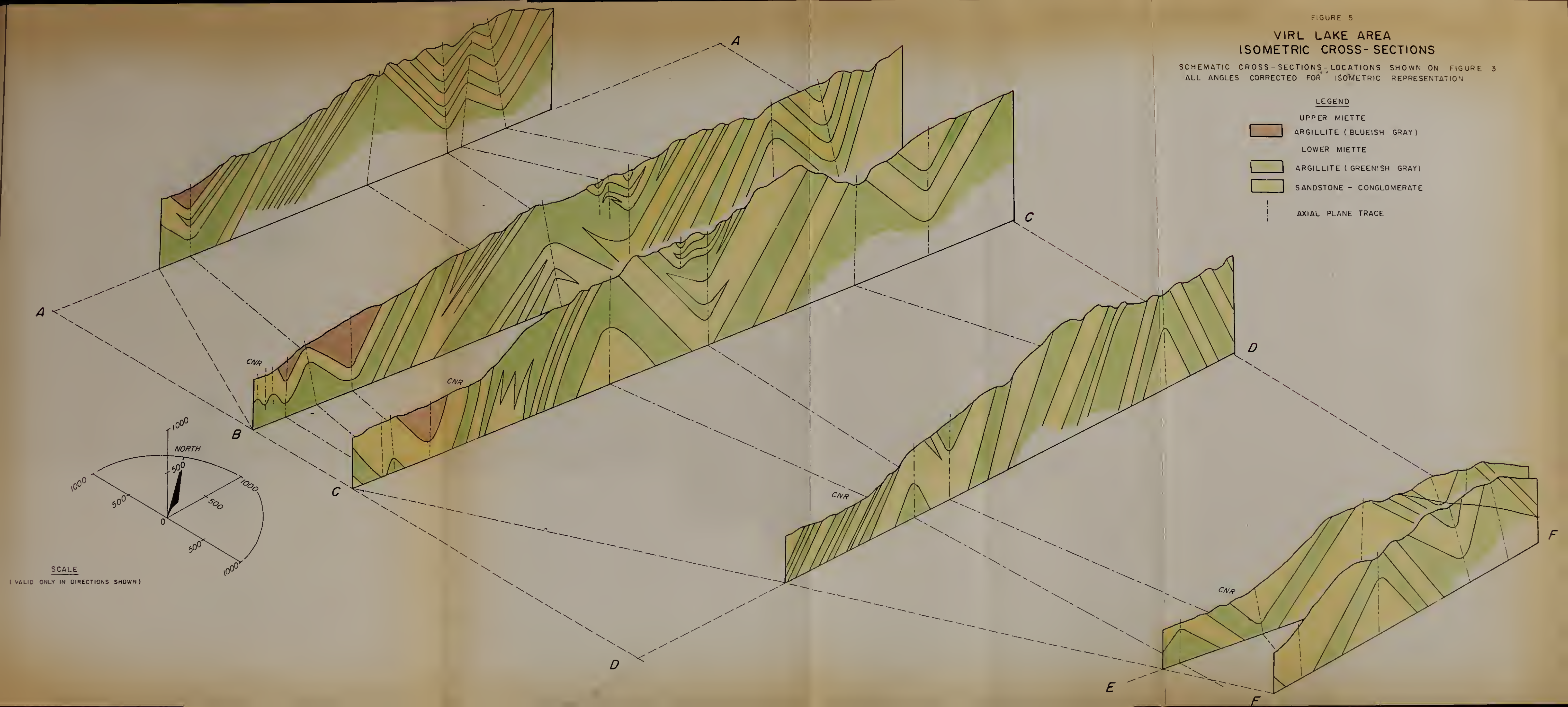
FIGURE 6

ROSE DIAGRAMS OF CROSS-STRATIFICATION

FIGURE 5

VIRL LAKE AREA ISOMETRIC CROSS-SECTIONS

SCHEMATIC CROSS-SECTIONS - LOCATIONS SHOWN ON FIGURE 3
ALL ANGLES CORRECTED FOR ISOMETRIC REPRESENTATION



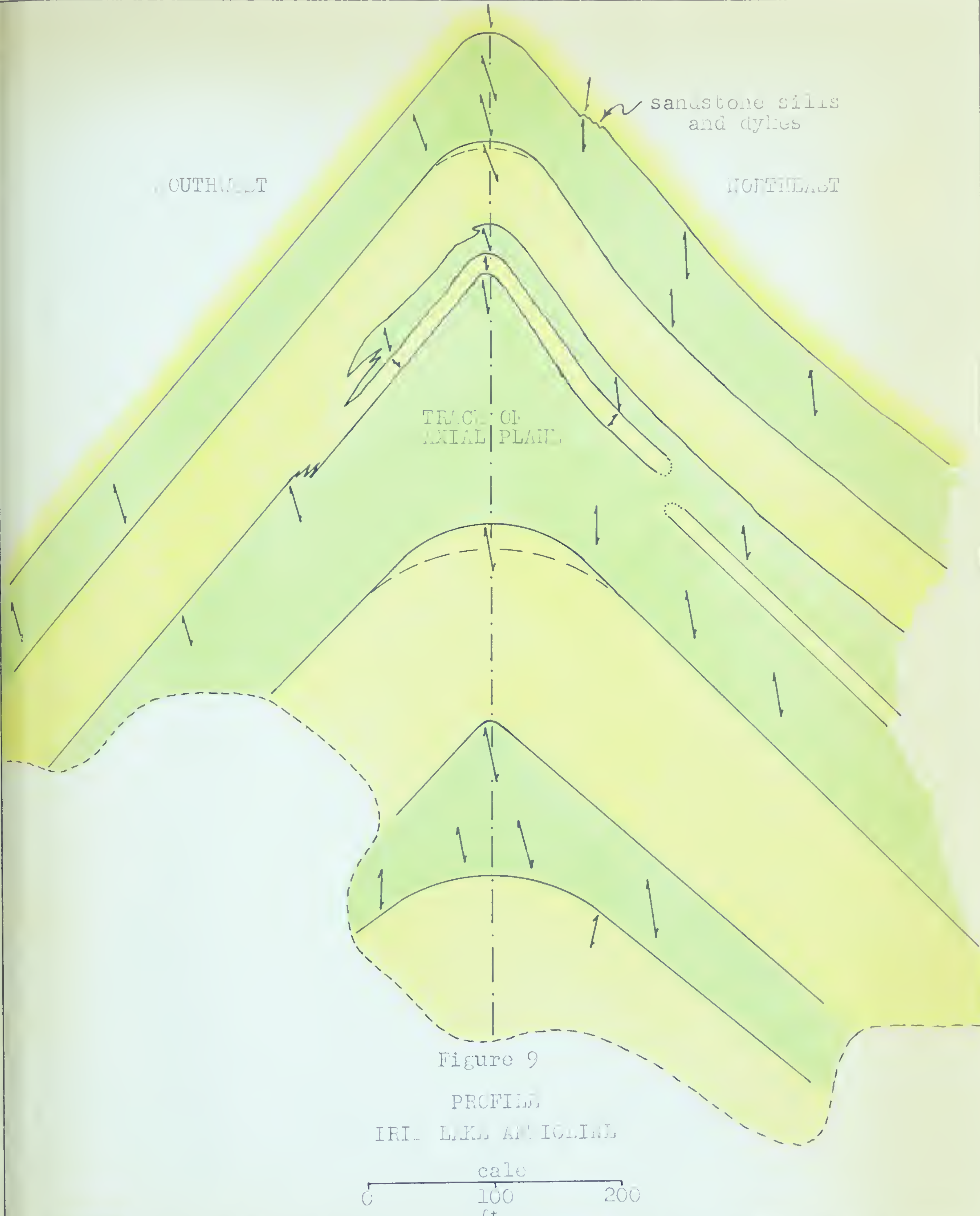


Figure 9

PROFILE
IRIS LAKE ANTICLINE

Scale

argillite and siltstone

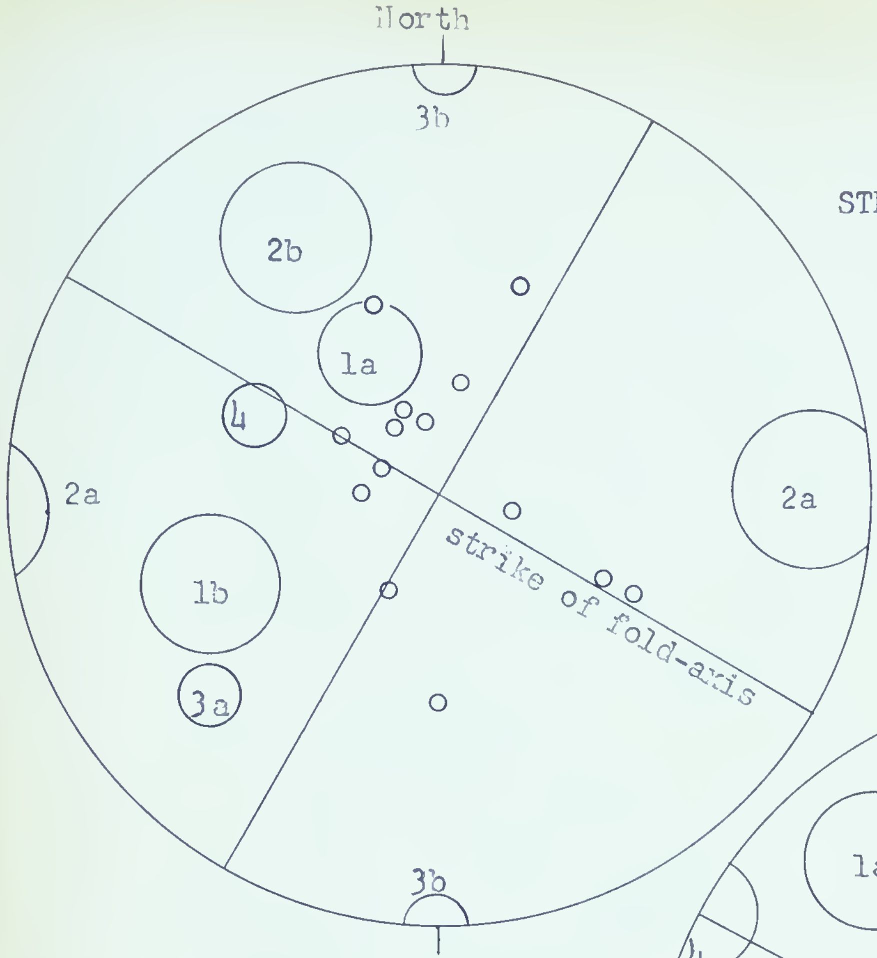
sandstone and conglomerate

cleavage

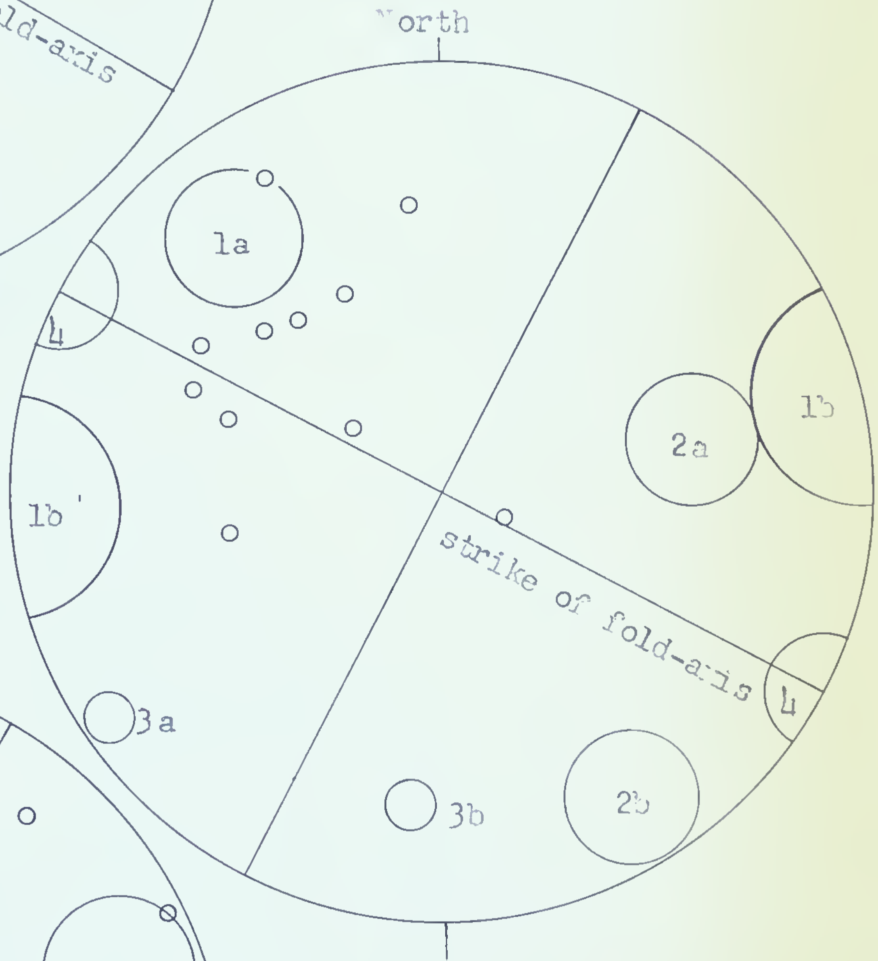
Figure 10

JOINTS

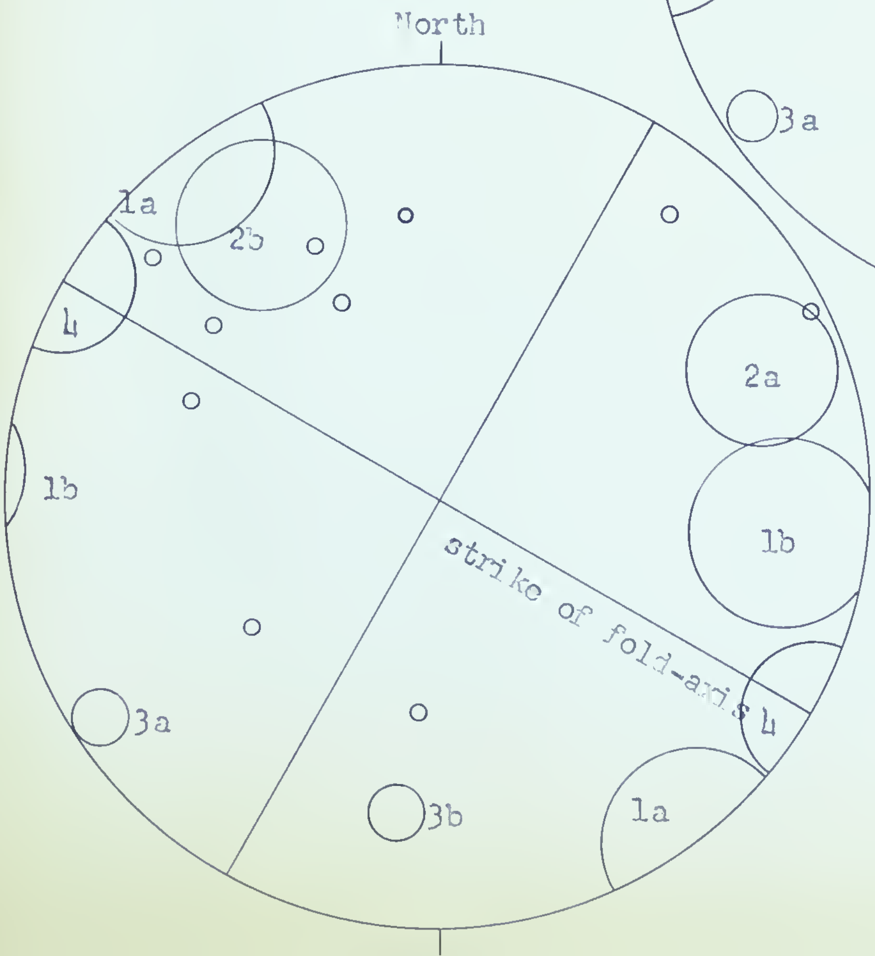
STEREOGRAPHIC REPRESENTATION



A
FIELD MEASUREMENTS



B
FOLD-AXIS HORIZONTAL



C
BEDDING AND FOLD-AXIS
HORIZONTAL

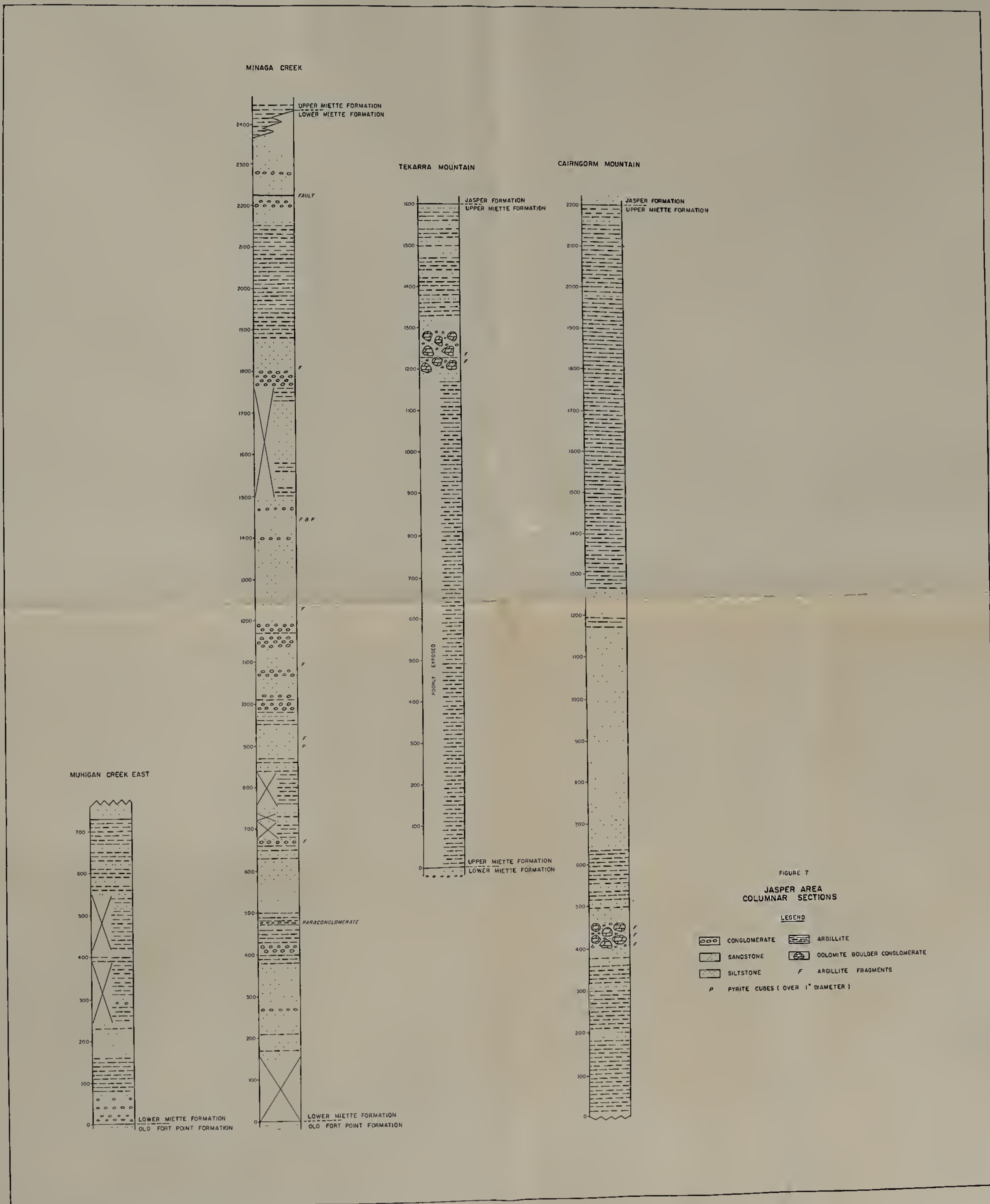


FIGURE 7

JASPER AREA
COLUMNAR SECTIONS

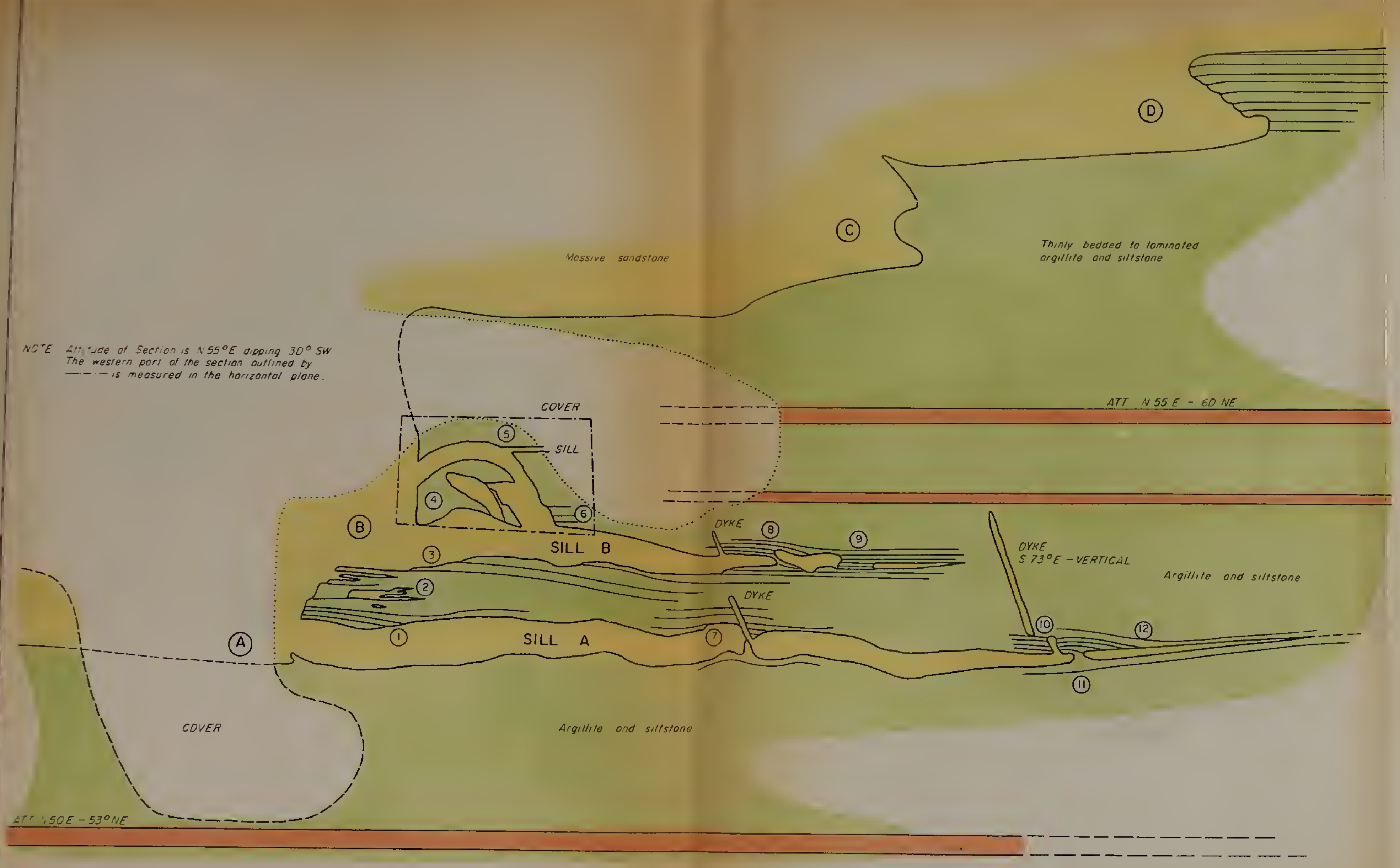


FIGURE 8

CROSS-SECTION THROUGH SANDSTONE DYKES AND SILLS

LEGEND

- BANDED SILTSTONE
- COARSE AND/OR PEBBLY SANDSTONE
- SILTY ARGILLITE
- BEDDING IN ARGILLITE
- LIMIT OF OUTCROP
- (A) BANK OF SCOUR-CHANNEL
- (1) POINTS REFERRED TO IN TEXT

SCALE

0 1 2 3 4

FEET